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A Problem in Railway Location—Notes and Queries.

THE LAST CABLE STREET RAILWAY in New York city has been converted into an open-conduit electric road. The Lexington Ave. and Columbus Ave. lines were recently changed over and on the night of May 25 the work of changing the Broadway line was commenced. The conductor rails had been previously installed in the cable conduit, but were left far apart in order to allow the passage of the cable grips. The work of conversion included drawing out the cable, removing the carrying wheels and placing the conductor rails in the proper position. Nearly 1,000 men were detailed for the work, and the electric cars were running regularly on the afternoon of May 27.

THE RAPID TRANSIT RAILWAY EXTENSION to Brooklyn has been approved by both branches of the New York Municipal Assembly, and it is expected that steps will be taken at once to award the contract for the work. The route of the tunnel submitted to the Municipal Assembly and approved by that body calls for an extension of the present Manhattan route from the City Hall down Broadway to Whitehall St., from the foot of which it will go under the East River to Joralemon St. in Brooklyn and thence to Fulton St., to Flatbush Ave., to Atlantic Ave., to the Long Island R. R. station. The estimated cost of the work is $8,000,000.

VIBRATIONS CAUSED BY THE NEW ELECTRIC UNderground railway in London has been reported upon by Lord Rayleigh's committee to the Joint Committee on Underground Tube Schemes of the Houses of Parliament. Personal inspection convinced them that a serious vibration is to be felt in many of the houses, and they ascribe the cause to the large proportion of the weight of the locomotives not borne by springs and to the want of rigidity in the rails. A new type of locomotive has been ordered in an attempt to correct the first cause of complaint, and the engineers are endeavoring to overcome the difficulties which have so far prevented the use of a stiffer rail. The committee awaits the results of these experiments before giving a more definite opinion.

THE TRAFFIC ON THE PARIS METROPOLITAN Railway is compared with that of the new electric underground railway in London in the Revue Generale des Chemins de Fer for April, 1901. The comparative records cover the period July 30 to Dec. 31, 1900, and the total of passengers in this period is 14,458,405 for the London road and 15,890,526 for the Paris line. The daily averages are 92,910 and 108,930, respectively, and the daily averages since the close of the Paris Exposition are 97,440 in London and 115,232 in Paris. The receipts for traffic, however, are highest for the English road, the daily average receipts since the close of the Exposition being 20,273 francs for London and 19,614 francs for Paris, or $4,054.60 and $3,922.80, respectively. This is explained by the fact that the London tariff is 2d., or 4 cts., throughout the line; while the Paris fare is 5 cts., 3 cts. and 2 cts., according to class and condition of sale of tickets. In 1900 in Paris 12,124,453 passengers bought second-class tickets, 1,769,758 bought return tickets and only 1,990,849 traveled first-class. On the other hand, says our contemporary, the London road cost about twice as much as the Paris underground to build, or 8,700,000 francs per kilometer, against 4,350,000 francs, or say $2,806,000 per mile for London and $1,403,000 per mile for Paris.

A CENTRAL RAILWAY TERMINAL STATION for Chicago was the subject of a paper read before the Western Society of Engineers on May 22 by Mr. R. C. Sattley, Division Engineer of Bridges and Buildings, Chicago & Northwestern Ry. The proposed site is on the west bank of the river, extending west to Canal St., between 12th and Harrison Sts., with a freight terminal south of 12th St. On the south side of Taylor St. would be a station for suburban traffic, 250 × 856 ft., with a trainshed 525 × 856 ft., extending to 12th St. On the north side of the street would be a similar station and trainshed for main line traffic, and extending to Polk St. A station for baggage, express and mail service, 856 × 700 ft., would be built between Polk and Harrison Sts. This central station would take the place of the present six terminal stations, all of which are more or less inadequate or inconvenient for the traffic which they accommodate, except that the Illinois Central R. R. station (and its suburban stations at Van Buren and Randolph Sts.) and the Chicago & Northwestern Ry. station might be left to provide for a portion of the suburban traffic of these lines. The paper showed that these stations at present accommodate 58% of the suburban traffic. The proposed station would have no stub tracks, and storage yards at either end would provide for empty trains to pull out of the way during the morning rush hours, and for empty trains to follow each other into the station for the evening rush. This would, of course, greatly increase the capacity as compared with stub tracks. For the freight traffic there would be 11 pairs of freight houses (one inbound and one outbound for each main road), with 22 team driveways. These freight stations would be two or more stories high. The greater part of the proposed site is already occupied by railway yards and tracks. The main streets between the terminal and the business section of the city would be widened, and an upper deck built exclusively for foot passengers, while an extension of the present elevated railway loop would be built to the station, and provision is made for connection with the proposed underground electric railway system.

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred at Oconto Junction, Wis., on the Chicago, Milwaukee & St. Paul Ry., on May 21. A train ran through an open switch and collided with another, wrecking both engines and killing one of the enginemen.

A VERY SERIOUS ACCIDENT occurred on the Albany & Hudson third-rail electric railway near Greenbush, N. Y., on May 26. Two cars, crowded with passengers and running at a high rate of speed, met while rounding a curve. Five persons were killed outright, including both the motormen, and a large number were seriously injured. The road is a single-track line with passing switches, and the cars appear to have been run on the plan of meeting at every switch. Frequent attempts of the motormen to reach a second switch are said to have resulted in previous minor collisions and the present disaster is supposed to have been due to a similar careless method of operation.

A SEVERE EXPLOSION in the Richland Mine of the Dayton Coal & Iron Co., of Dayton, Tenn., on May 27, resulted in the deaths of 21 men. The explosion was due to a collection of dust which was set off by a blast of dynamite.

DAM FAILURES ARE REPORTED from Colorado and Texas. A new dam on Holliday Creek, about six miles from Wichita Falls, Tex., broke on May 19. The dam was of earth, and was built for irrigation. It appears to have been in the hands of the contractors, as the reports state that a leak was discovered on May 18 and repaired by the contractors by 5 p. m., but that another leak occurred at 7 p. m. This could not be stopped, and the dam broke at 1:30 a. m. May 19. The break is said to have been some 200 ft. long.——The failure in Colorado appears to have been caused by an inadequate spillway at the dam forming a reservoir on Pike's Peak for supplying water to Victor, Colo. The earth between the spillway and the dam and a few feet of the dam was washed away. Another dam in the vicinity, impounding water for the supply of Altman, was completely washed away.

MUNICIPAL OWNERSHIP OF WATER-WORKS at Denver, Colo., appears to have received a decided setback by the cancellation of a contract which the city made a few months ago for the sale of $4,700,000 of water bonds. A small portion of the bonds had been actually delivered when a taxpayer brought suit to test the validity of the bond issue. Meanwhile a new city administration has come in and now the sale has been cancelled. One side claims that both parties were anxious to cancel the contract pending the protracted lawsuit which is expected. The other side says the suit was brought at the instance of the Denver Union Water Co., that the company has induced the present authorities to cancel the contract, and that the suit to test the validity of the bonds will now be dropped.

IMPROVED MEANS OF SEWAGE DISPOSAL in the lower Passaic Valley will be studied, it is understood, by the New Jersey State Sewerage Commission. Governor Voorhees has stated that he will turn over to the commission a portion of the emergency appropriation under his control. The exact sum to be made available is not stated, but $8,000 has been mentioned. The secretary of the commission is Mr. Boyd McLean, Fuller Building, Jersey City.

PROGRESS ON THE SIMPLON TUNNEL is reported by U. S. Consul H. L. Washington, of Geneva. On Dec. 31, 1900, the total distance driven from the two headings was 23,835 ft. on tunnel No. 1 and 23,727 on the parallel tunnel No 2, or a total of 4.51 miles out of the 12.23 miles lying between the two entrances. The advance made in 1900 amounted to 11,155 ft., or an average of 31.4 ft. per day from the two ends. This average for 1899 was about 30 ft. The average number of workmen employed in December, 1900, was 3,915. For the tunnel and its lines of approach the sum of $4,940,800 has been expended to Sept. 30, 1900.

THE SAVANNAH HARBOR CONTRACTORS whose removal from New York to Georgia has been ordered by the court for trial on the charge of complicity in the Carter frauds have given bonds for their appearance there at the next term of the U. S. Court, to be held in August next.

THE HAVANA FLOATING DRY-DOCK was launched at that place on May 20, and will be ready for use in about two months. It will take a vessel of 6,000 tons. At the present time the Spanish floating dry-dock is being used.

APPROPRIATIONS FOR CANADIAN WATERWAYS improvements have been voted by the Dominion Parliament to the following amounts:

Welland canal works	$430,000
Port Colborne harbor	40,000
Galops canal	135,000
Lachine canal	591,000
Sault Ste. Marie canal	100,000
Soulanges canal	100,000
Cornwall canal	110,000
Farran's Point canal	10,000
Lake St. Francis	15,000
Rapide Plat canal	75,000
Galops canal	330,000
North channel	30,000
St. Lawrence ship channel	419,000
Hydraulic dredge	250,000
Montreal harbor	250,000
Light houses and buoys	453,000
Grain elevators at Montreal	1,000,000
Total	$4,338,000

THE SOLAR ECLIPSE EXPEDITION sent to Sumatra by the Massachusetts Institute of Technology reports some important results. The weather was cloudy during a portion of the eclipse, but all four contacts were observed and a brilliant corona was shown at totality, which lasted nearly six minutes. The most interesting and novel work of the expedition consisted in the observations obtained photographically of the shadow bands. There are black bands which are seen reaching along the earth's surface just before and just after the moon's shadow. No eclipse party has ever before made any attempt to photograph them.

THE NEW ELECTRIC STORAGE BATTERY recently invented by Mr. T. A. Edison was described by Dr. A. E. Kennelly in a paper read at the recent annual meeting of the American Institute of Electric Engineers. The advantages claimed for the new cell are: (1) Absence of deterioration by work; (2) large storage capacity per unit of mass; (3) capability of withstanding careless treatment; (4) capability of being rapidly charged and discharged; (5) inexpensiveness. The negative pole, corresponding to the zinc of a primary cell, is iron. The positive pole is a superoxide of nickel believed to have the formula NiO_2. The electrolyte is an aqueous solution of potash. The initial voltage of discharge after recent charge is 1.5 volts. The mean voltage of full discharge is approximately 1.1 volts. The normal discharging current rate per unit area of active element (positive or negative) is 0.06 amperes per sq. in. The storage capacity of the cell per unit of total mass is 14 watt-hours per lb. or 53.3 lbs. per electrical HP.-hour, as against 4 to 6 watt-hours per lb. for the ordinary lead accumulator. The mean normal discharging power-rate per unit of mass of total cell is 4 watts per lb., corresponding to a normal discharge period of 3½ hrs. The cell may, however, be discharged in approximately one hour, or at a rate of 12 watts per lb.

SOME RECENT DESIGNS FOR STEEL COAL-HOISTING TOWERS.

By H. G. Tyrrell.*

Until recently most of the coal hoisting towers along the wharf fronts of the seaboard cities have been constructed of wood as, also, have been the pockets to which they deliver their coal. With the introduction of steel construction, however, many of these structures are now being built of steel, which is, of course, more expensive than the old timber construction, but which makes an altogether safer and more satisfactory tower. These towers are either built independently or are rigidly connected to the house and pocket below. If independent, as in the case of the tower shown by Fig. 1, designed and built for the Dominion Coal Co., of Montreal, the tower is mounted on wheels and travels over the entire length of the coal storage pocket. Another tower, for the Metropolitan Street Ry., of New York city, is rigidly fastened to the framework of the pocket beneath it, the tower itself having no traveling motion. Still another method is to build the tower and house containing the crusher platforms and weighing hoppers all in one, having the whole mounted on wheels that travel on rails at the ground level. A design of this kind was recently made by the writer for the new power plant at Lincoln wharf, Boston. Two towers of this latter type have recently been built for the Walker Coal Co., at Portsmouth, N. H.

The tower for the Metropolitan Street Ry., in New York, has a tower 55 ft. in height, and 24 ft. square at the base, with a single boom 31 ft. in length overhanging the water. The tower is built with four legs strongly braced together and the lower part contains an engine room from which the hoisting is controlled. The engine house is, of course, roofed over and enclosed on the sides with corrugated iron, having also windows to admit the light. The hopper was constructed of 5-16-in. plates, connected by a frame of angles and channel irons. The whole tower was designed to carry a live load of three tons at the end of the boom, having an allowance of 100% for impact. It contained 18 tons of steel and cost, including floor, roof and sides, $2,250.

Another tower was designed and built for the Dominion Coal Co., at Montreal, Canada, somewhat similar to the last. It has a height of 63 ft. and a boom of 51 ft., with an area at the base 29 ft. long and 25 ft. wide. The boom is swiveled at the rear end and was designed to carry a live load of 3½ tons with a provision for 100% impact. It will be noticed from Fig. 1 that the floor construction is very heavy, being made of 12 and 18-in. I-beams. The tower is provided with a ladder on one side, enabling the operator to go up and oil the pulley bearings. The total load figured at the end of the boom is 18,000 lbs. The whole tower is mounted on seven wheels and has a safety clamp at the rear side to prevent tipping. This tower contained 27 tons of steel besides the trolley rope and operating machinery. The hopper in this case is plank lined and the house was enclosed with wood.

Fig. 2 is a view of the steel coal hoisting towers for the New England Gas & Coke Co., at Everett, Mass.

*178 Devonshire St., Boston, Mass.

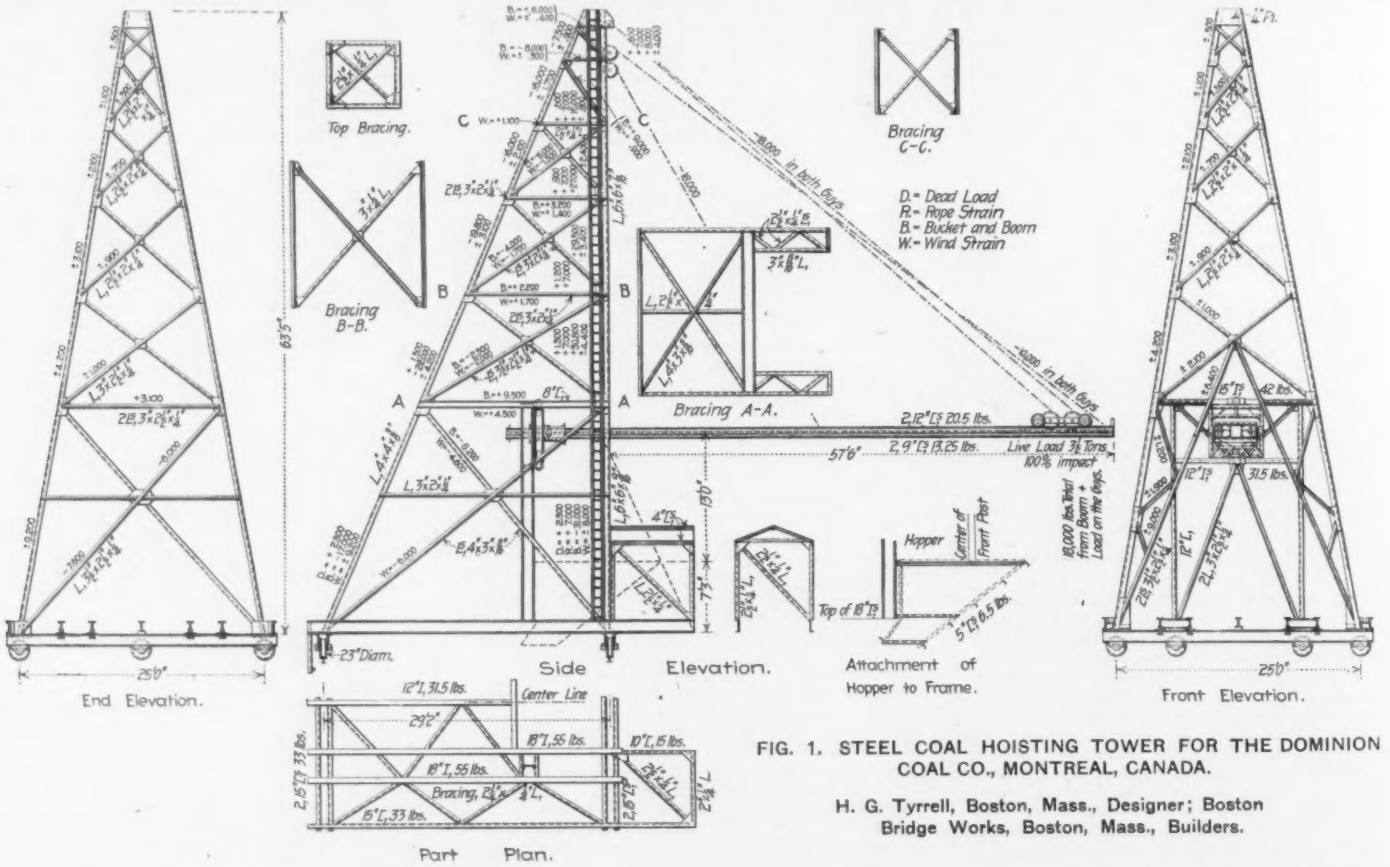


FIG. 1. STEEL COAL HOISTING TOWER FOR THE DOMINION COAL CO., MONTREAL, CANADA.

H. G. Tyrrell, Boston, Mass., Designer; Boston Bridge Works, Boston, Mass., Builders.

THE INFLUENCE OF TITANIUM ON THE PROPERTIES OF CAST-IRON AND STEEL.*

By Auguste J. Rossi, M. Am. Inst. Min. E.†

Titanium is found in nature almost as abundantly as iron itself. Titaniferous iron ores are met all over the world, and in Sweden, Norway, Canada, in several States of the Union, and particularly in the Adirondack district, they occur in "mountain masses," penetrating the igneous rocks, and constituting, in fact, the geological formation, the igneous rocks themselves being so impregnated and enriched with the iron-bearing mineral as to justify their being called an ore.

It is not within the province of this paper to discuss the question of their smelting. It will suffice for our purpose to say that these titaniferous ores have been successfully smelted in blast furnaces for over 20 years in the Adirondacks (some 50 years ago), in England at Norton-on-Tyne for several years, and by ourselves more recently, and that we have obtained hundreds of tons of pig-iron, which have formed the basis of some of the experiments which we intend to describe.

Whatever may have been said of the economy of this smelting, one point on which all metallurgists seem to agree is the peculiar value possessed by the pig-iron which they yield. Though at the temperature available in the blast furnace the oxide of titanium is not reduced by carbon, owing to other combined influences, a certain amount of titanium finds its way into the metal, but always in very small proportions, rarely above 0.10% to 0.2% or 0.3%, most generally a few hundredths, or even traces. So far as these ores have been smelted, and, we should say, in the conditions in which they have been smelted, the pig-iron yielded is eminently a forge iron, an ideal open-hearth stock, low in silicon, quite free from phosphorus and sulphur (as these ores are, as a rule, generally free from phosphorus especially), and containing the carbon mostly in the combined state. The fracture is close-grained, very much in appearance like steel, of which it has the grayish color rather than being white. This iron is very strong. Such expressions as "wonderfully good," "all that can be desired," "very tenacious pig," "extra good iron, imparting to others in mixture properties of cold toughness" • • • will be met in technical publications here and abroad whenever this pig-iron is mentioned.

The "titanic pig" which we smelted from Adirondack ores contained but 0.11% to 0.13% silicon, and about 0.20% titanium; another, also smelted by us, contained silicon, 0.36%; titanium, 0.07%; combined carbon, 2.69%; graphitic, 0.24%. As only a very small percentage (5%, or thereabouts) of this pig was used in mixture with others in the tests described further, the results observed cannot very well be attributed to the direct influence of titanium, but rather to an indirect action, a remark which has been made very often by technical men.

It was as entering as a constituent for chilled castings that we had occasion to experiment with pig-iron of this class for a large manufacturing firm. Test bars 1 in. × 1 in. × 13 ins. long, tested 12 ins. between supports, broke under a load at center of 2,700 lbs.; average of three bars.

The normal mixture used in this establishment, and which formed the basis of all mixtures, had an average transverse strength (three bars) of 3,390 lbs., bars of the same dimensions as above, and a chill of 1.062 ins. on chill blocks 1½ ins. × 1½ ins. × 2 ins.

EXPERIMENTS WITH NICKEL ALONE.—The first experiments bore on the influence of additions of nickel to the normal mixture. We prepared for the purpose a ferro-nickel at 30% nickel. Cast bars 2 ins. × 1 in. × 2 ft. long of this ferro could be bent at right angles without breaking. Regular bars 1 in. × 1 in. × 12 ins. between supports gave way under a load of 2,450 lbs. at center, but not by breaking or snapping asunder, as is the case with cast-iron, but by bending gradually until the deflection at the center reached much over 1 in., when they generally split open in the length. Of this ferro-nickel we added to the normal mixture a sufficient quantity to obtain in the product increasing quantities of nickel of ½%, ¾%, 1%, 2%, 3%, 4%, 5%, 6%. At the same time as the bars, chilled blocks were cast in each case. The bars had the dimensions adopted for all others, viz.: 1 in. × 1 in. × 12 ins. between bearings, 13 ins. long. The fol-

*Abstract of a paper presented at the Milwaukee meeting (May, 1901) of the American Society of Mechanical Engineers.

†35 Broadway, N. Y.

lowing diagram (Fig. 1) shows the results, taking the average breaking loads of three bars in each case as ordinates.

An inspection of this diagram shows that the transverse strength is decidedly increased (about 20%) by additions of small quantities of nickel up to 1%; after that this increase of strength diminishes to 5% for quantities of nickel reaching nearly up to 3%, and then the strength remains stationary, or actually diminishes. In fact, for these higher percentages of nickel, the bars bend to such an extent at the center when a certain load is reached that the observations become difficult and uncertain.*

But the effect of additions of nickel on the chill is remarkable. From 1 1-16 ins. with normal mixture it drops to nothing with 6% nickel, and even the addition of 0.50% nickel is enough to cause it to drop considerably below the normal; 0.875-in., as against 1.062 ins.

EXPERIMENTS WITH NICKEL AND TITANIC PIG.—By additions to the normal mixture of ¾% nickel and 5% titanic pig, the breaking load reached 3,750 lbs. average, an increase of about 10% above the normal, and the chill 1.125 ins. In other words, an addition of 5% titanic pig brought back the chill to be fully equal to or greater than the original, while the strength secured corresponded to that obtained with 1% nickel, without addition of titanic pig.

By adding to the normal mixture ½% nickel and 10% titanic pig, the average breaking load reached 3,700 lbs., practically the same as above, while the depth of the chill reached 1.312 ins.; in other words, the result of the addition of titanic pig to a great extent (10%), with less nickel (0.50%), is to increase considerably the chill without impairing the strength. (Fig. 1.)

EXPERIMENTS WITH TITANIC PIG ALONE.—We experimented next with titanic pig alone, without additions of nickel. The diagram Fig. 2 summarizes the results obtained. A consideration of the latter shows that the addition of 2½% titanic pig increased the chill slightly, without any apparent action on the strength. An addition of 5% titanic pig increased the strength about 10% and the chill considerably more, about 30%; while an addition of 10% to 25% of titanic pig, without impairing the original strength—on the contrary rather increasing it to an important extent—increased the chill to 50% or more above the normal.

The action of this titanic pig added to cast-iron is then shown by the diagrams to be an increase in the strength with an increased chill or a maintenance of the strength with a considerably greater chill, as much as 50% greater or more. To all purposes, this addition is then preferable to that of nickel; on the score of cost, as to effect on the chill, and because, practically, the same strength can be secured without nickel addition as with it, within the limits of chill admissible. Results, observed on bars, were confirmed on castings made from these different mixtures.

The titanic pig containing, at the most, 0.2% titanium, the addition of 5%, or even 10%, of such pig could not introduce in the mixture (assuming no loss of any kind) more than 0.01 to 0.02% titanium as an outside figure, and to such small percentages, if any, it is rather difficult to attribute the results observed. By whatever cause they may have been secured, it was natural to study the action on the properties of cast-iron that the addition of an alloy could have containing a sufficient amount of titanium to introduce in a pig-iron larger quantities of the former metal than mere traces. Such alloys we have manufactured by the ton last summer, by different processes. Some of the alloys we have obtained contained but very small percentages of carbon—0.18% to 0.70%, and from 10% to 75% titanium; others, on the contrary, contained carbon from 5% to 7%, or even 8% and 10% to 12% titanium, occasionally as much as 15% to 20%. This carbon was present almost invariably in the graphitic state, the combined carbon hardly reaching 0.20%, generally 0.12% to 0.15%, with S, 0.011%; P, 0.04% to 0.09%; silicon below or up to 1% to 1.50%. It is this latter class of alloys which we have used to season pig-iron, with the results described below.

EXPERIMENTS WITH CAST-IRON TREATED BY ADDITIONS OF TITANIUM ALLOYS.—We have added the alloy both in the crucible and in the pouring ladle; coarsely granulated, or even in lumps. Our experiments have been repeated by other parties in a large construction works and in car-wheel works, and our own results, as to extent of improvements observed, have been fully confirmed. We will not insist here on the different methods which we have tried in order to secure a better incorporation of the alloy. Adding the alloy previously heated, and in as small fragments as practically admissible, secured, of course, the best results. We have not experimented yet by adding the alloy in the cupola; but in all our experiments, and in those made by others, we have found that an addition of 4%, in some cases even less, of the 10% alloy was ample to secure a considerable improvement, both in the transverse and tensile strength of the metal.

*Tensile strength tests would certainly show much better figures for nickel.

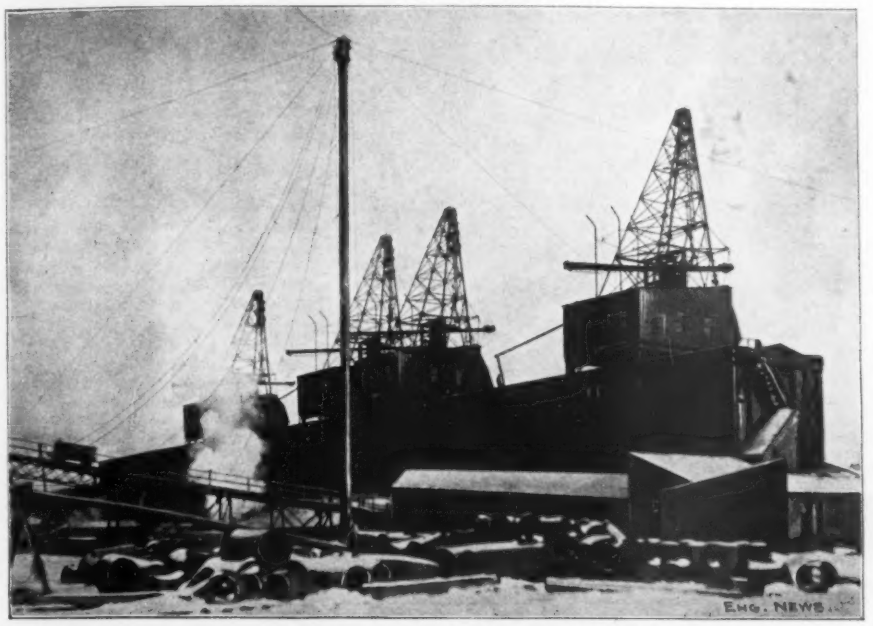


FIG. 2. VIEW OF STEEL COAL HOISTING TOWERS FOR THE NEW ENGLAND GAS, COAL & COKE CO., EVERETT, MASS.

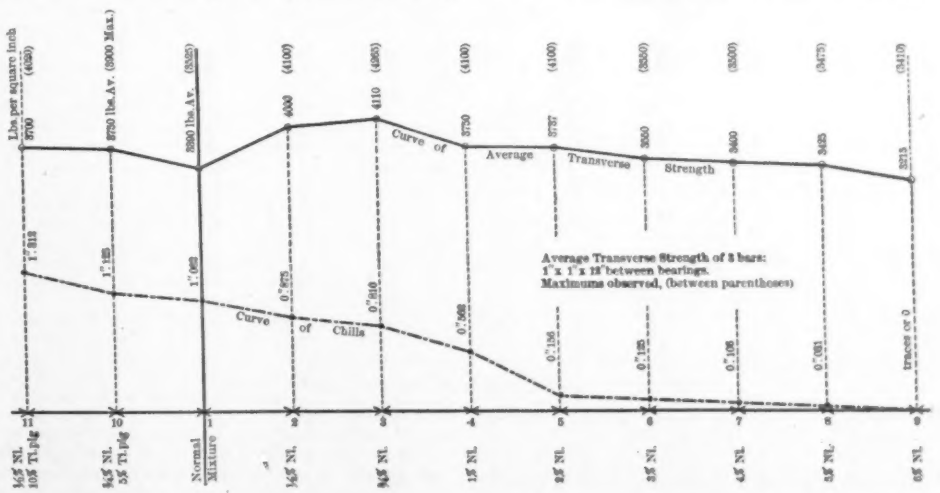

Lbs per square inch
Curve of Average Transverse Strength
Curve of Chills
Average Transverse Strength of 3 bars:
1" x 1" x 12" between bearings.
Maximums observed, (between parentheses)
Normal Mixture

FIG. 1. DIAGRAM SHOWING RESULTS OF EXPERIMENTS WITH NICKEL AND PIG IRON ADDED TO NORMAL MIXTURE.

These 10% to 12% titanium alloys are much lighter than pig-iron, the specific gravity of titanium being less than 5, and for this reason they have the tendency to float on the surface of the metal treated. Enclosing the alloy in a cast-iron pipe, dropped hot in the bath of molten pig when operating on a ladle would prove very successful.

Fig. 3 summarizes the results obtained by the addition of 4% of a 10% to 12% titanium alloy containing carbon to pig-iron of different quality.

It shows that by such an addition we have secured an increase of some 20% to 25% in the transverse strength, and from 30% to 50% in the tensile strength of the metal, according to the nature of the pig-iron treated. This result can be obtained at an expense which does not materially increase the cost of the product, if we take in consideration the improvements secured, the small amount of alloy found sufficient to secure them, and the cost of the alloy which we have been able to manufacture at such a low price as to admit of its industrial use. In many cases, indeed, the high requirements of specification for superior products suppose a higher price for the cast-iron fulfilling them, and the addition of the alloy, by improving indifferent pigs and bringing them up to the mark, would prove even economical, the value of the alloy for the purpose once established without contest.

Analyses made of the pig-iron, before and after treatment, showed practically the same amount of graphitic and combined carbon, the same ratio of one to the other, with no differences or but trifling ones as to silicon, sulphur, phosphorus and manganese. The only element distinguishing them was titanium, present in the metal treated to the extent of 0.34% to 0.37%, and 0.47% to 0.53%. In these cases the percentages found are sufficient to have a direct influence on the quality of the metal, and the results show strongly in which direction.

The deflection curve (at center of bars) corresponds quite well with the increased tensile strengths, and the curves representing this latter strength and the transverse strengths in the original metal and the metal treated are so nearly parallel (as soon as the pig-iron under experiment is not of an inferior quality) that the improvements observed seem to follow a law, and cannot be called casual.

We may remark here that the sizes adopted for the test bars—square bars 1 in. × 1 in. × 12 ins. between supports for transverse strength, ¾-in. to 1 in. diameter × 18 ins. long for tensile strength—may not be considered by many as the best size to adopt in such tests. Nor, we may say, were the deflections at center measured with such an accurate instrument as would be strictly required, but all the experiments were made on the metal before and after treatment, with test pieces cast in the same conditions, tested in the same machine, measured with the same instrument, and they have at least the merit of being comparative.

We should add, also, that in all the tests made in crucibles our invariable practice was to melt the same amount (50 lbs.) of the original pig-iron experimented with, casting from it three round bars and three square bars, and, when they were justified, chill test blocks.

The new charge consisted of 50 lbs. of the same original pig-iron, to which was added the proper proportion of titanium alloy broken in sufficiently small fragments. From the well-melted mixture were cast the regular size test bars, as also chill blocks, when the condition of the experiment implied it, thus affording a good comparison of the properties of the metal before and after treatment.

When operating in the ladle (in car-wheel works, for instance) our practice has been to take from the pouring ladle, into a smaller ladle, the quantity of metal not treated necessary to cast the test pieces, and then cast

the wheel from the original metal. The pouring ladle was then half filled with hot metal from the receiving ladle from the cupola, the intended amount of comminuted alloy dropped in, the charge in the pouring ladle completed, the mass stirred, and a sufficient quantity of treated metal taken for test pieces before casting the wheel.

The figure of 4% of alloy in weight of the pig metal is based on the weight of the wheel and gates as cast, and is then a maximum, as necessarily there always remains a certain variable amount of metal in the pouring ladle. Furthermore, if the alloy be used in too large pieces or is imperfectly stirred, a part of it is not thoroughly incorporated, and may remain floating on the metal. These circumstances may serve to explain certain discrepancies in the curves, which represent the results of practical tests and experiments.

EXPERIMENTS WITH STEEL.—Our experiments with steel have been limited, so far, to crucible steels. Wm. Metcalf, in his "Manual for Steel Users" has called attention to the possible influence of gaseous elements present in steel and not generally determined, such as hydrogen, oxygen and nitrogen. As to oxygen, it is practically and sufficiently removed in general by the addition of ferro-manganese; but it is not so with nitrogen, of which the influence is considered by Percy and many other metallurgists as decidedly weakening. Analyses made by Professor Langley of crucible open hearth and converter steel have revealed the fact that the quantities of nitrogen found in these three classes of steel keep decreasing from the first to the last, and, as is well known, the qualities of strength of these different steels, even for the same composition, with respect to silicon, sulphur, phosphorus, carbon, place the crucible steel at the head, and the converter steel the last. Mr. Metcalf has then suggested that the removal of nitrogen by some chemical affinity would be likely to improve the metals containing the most of it; that is, the open hearth and the converter steel, and even the crucible steel, to the extent of the nitrogen it contains also, and in this line of ideas he has suggested the use of titanium for the purpose.

The affinity of titanium for nitrogen is indeed so great that titanium will burn in nitrogen just as iron burns in oxygen. If such is the case, improvements in steel—even in crucible steel—could be secured by a very small addition of the alloy, and even if but a very small percentage of titanium were to be left in the treated metal. This, of course, would be independent of any specific action which titanium, by its presence in more important amount, could have on the properties of steel, as we have found it to be the case with cast-iron.

But experiments with crucible steel are difficult to carry on. It is necessary, when making them, that the metal obtained from a blank charge, without addition of alloy, should have the same composition as that obtained in a charge to which the alloy has been added. This is readily enough secured, as far as silicon, manganese, sulphur and phosphorus may be concerned, but not so as regards the carbon; and differences in the percentages of this latter element may at once change a soft steel to a mild or hard steel, or vice versa—steels possessing entirely

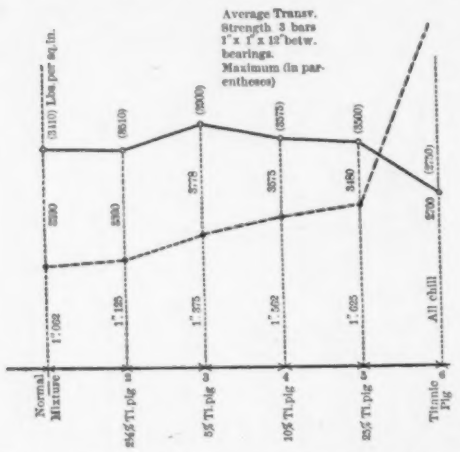


Fig. 2. Diagram Showing Results of Experiments with Titanic Pig Iron Alone, Added to Normal Mixture.

different properties and not comparable. In making the tests described below we have used alloys practically free from carbon, made by a special process. They contain some 1% silicon, more or less, S, 0.0111%; P, 0.04 to 0.09%, or even less, and aluminum occasionally; and of these alloys we have added from 2 to 5% to the steel, according to the percentage of titanium expected to be introduced and percentage of titanium in the alloy itself. The titanium alloys are so much more difficult to melt that they are higher in titanium, and, in general, we would not advise the use of alloys much above 15% titanium (at least for crucible steel).

We have chosen amongst the tests we have made such as are, we believe, the most characteristic, and for lack of direct terms of comparison with steels resulting from the same charges but not treated with the alloy, we offer steels of very nearly the same composition as to silicon, sulphur, phosphorus and even aluminum, and containing the same amount of carbon. They are taken from Mr. R. A. Hadfield's paper on "Aluminum Steel":

	Carbon, p. c.	Titanium, p. c.	Alum. p. c.	Elastic limit, lbs.	Ultimate strength, lbs.	Contraction area, p. c.	Elongation, p. c.
Hadfield	0.49	"	0.31	30,414	73,248	22.28	18.50
Titanium steel.	0.479	"	0.30	35,000	81,250	38.80	24.40
Hadfield	0.65	"	0.18	32,211	58,912	4.40	3.50
Titanium steel.	0.68	"	0.20	41,000	103,000	17.40	26.80
Hadfield	0.85	"	0.20	35,549	91,100	4.40	4.50
Titanium steel.	0.854	"	0.29	76,500	141,500	14.60	8.40
Titanium steel.	0.826	"	0.31	70,000	127,500	21.90	8.40
Titanium steel.	1.227	0.53	0.00	59,250	—d	30.90	10.00
Titanium steel.	2.165	1.07 } 1.10 }	.0	65,000	—d	10.50	8.75

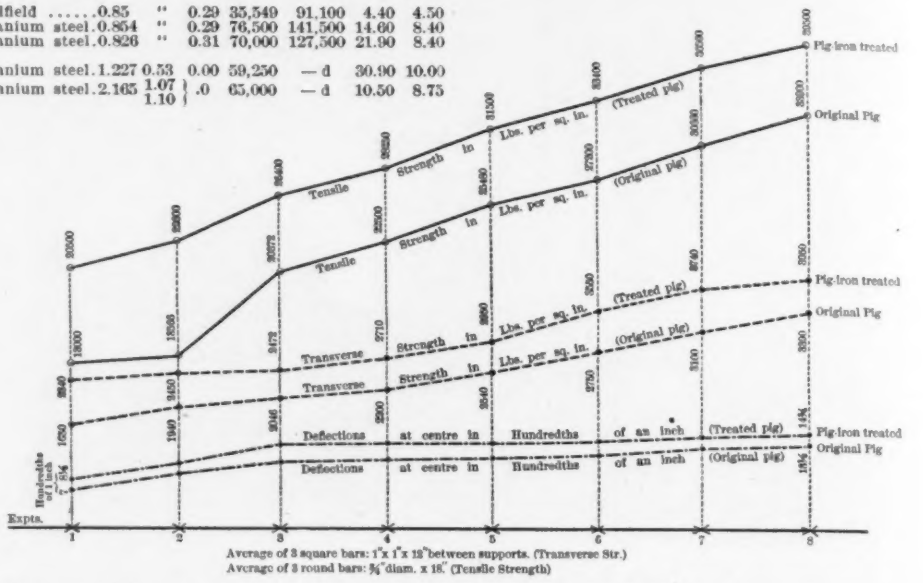

Pig-iron treated
Original Pig
Tensile Strength in Lbs. per sq. in.
(Treated pig)
(Original pig)
Transverse Strength in Lbs. per sq. in.
Deflections at centre in Hundredths of an inch
Expts.
Average of 3 square bars: 1"x 1"x 12" between supports. (Transverse Str.)
Average of 3 round bars: ½" diam. x 18". (Tensile Strength)

FIG. 3. DIAGRAM SHOWING RESULTS OF EXPERIMENTS WITH FERRO-TITANIUM AND CAST IRON, SHOWING EFFECT OF ADDITION OF 4% ALLOY AND 10 TO 12% TITANIUM ON STRENGTH.

All the steels treated with titanium contained about 0.10% titanium when not otherwise mentioned. The test bars were 0.505 diameter, 2 ins. between clutches, threaded as required by the regulations of the United States Government.

The alloy was added in small fragments or even granulated in the crucible with the charges, and in some cases dropped in that state into the molten steel; but it would have been much preferable to enclose it in an iron pipe, heat the latter, and drop it into the molten steel or add it cold with the charge, in the pipe, as it is practiced with other ferros. A great deal of the alloy, and consequently of the titanium, was lost by oxidation as it floated on the surface of the molten bath of steel, the alloy being considerably lighter than steel, especially when high in titanium, as we have had occasion to remark.

As far as these experiments did go, and we made some 1,200 or 1,500 lbs. of ingots, they seem to show a remarkable elongation and reduction of area; in high or very high carbon steel, titanium appears to act somewhat like nickel in this respect. Chisels, crowbars, cutting tools, were made from such steel, and they were declared to be excellent. The chisels kept their temper well, being tempered hard, but did not waste on the head under the blow of the hammer—they "mushroomed," as the workmen expressed it. Our experiments in this line, however, are far from being complete, and others are in progress, or will be soon, in open hearth and in the converter. It is possible that for the two latter applications alloys higher in titanium than 10 to 12%, or even 15%, proved very admissible.

The alloys high in carbon could certainly be used instead of those practically free from it—even for crucible steels. A 10% alloy, containing, say, 7% C, added to the extent of, say, 4 lbs. to 100 lbs. of steel, would introduce in the steel only 0.28 carbon. That is much less than the steel treated is intended to contain, let it be a semi-hard and specially a tool steel, in which case the carbon expected is to reach 0.50 to 0.90 and more, or thereabouts, and it would be only a matter of adjusting the carbon-bearing materials of the charges to take care of the carbon supplied by the alloy.

CONCLUSION.—In conclusion, we believe ourselves justified in saying that, as far as cast-iron is concerned, the improvements observed by additions of small percentages of titanium alloys cannot be contested, corroborated as our results have been by experiments made by others and independently from us. They bear both on the transverse and tensile strength, which are increased, the former some 20 to 25%, the latter 30% or more, according to quality of the original pig-iron.

As to steels, limited as our experiments have been, and limited to crucible steel as they were, the influence of titanium seems to have been very much in the same direction as for cast-iron—an increase in the ductility of the metal, as shown by the increased contraction of area and elongation and of the elastic limit in high carbon steels.

We have purposely avoided in all the above any mention of the manufacture of the alloys, desiring to examine particularly in this paper the influence of titanium on the properties of iron. A few succinct details, however, on the methods which we have followed may prove of interest, as some bear a direct relation to the production of alloys of titanium with other metals than iron.

Any titaniferous iron ore, sufficiently free from injuri-

ous elements and high enough in titanium, will prove suitable for a first material. The powdered ore is intimately mixed with powdered charcoal, and the mixture charged in the graphite cavity of a block forming the electric furnace, or crucible. Its construction is very much like that described by Siemens some 20 years ago. This graphite block and its contents form the cathode. A set of carbons, bunched together and forming the anode, penetrates in the central cavity of the furnace, leaving between the carbons and the sides of the crucible a space sufficient for the introduction of the charge. The lowering or raising of the carbon anode, by means of any appropriate mechanical device, allows the arc to start through the mass, the heat generated being sufficient (probably some 2,800° C, more or less) to cause the reduction of titanic oxide by carbon, a reduction which requires this intense heat, the iron oxides of the ore being, of course, readily reduced in these conditions. The two metals melt, and alloy and the earthy materials of the ore float as slag on the surface of the metallic bath. With the ores which we have used the amount of this slag was very limited. The proportion of titanium to the iron in the ores treated necessarily fixes and limits the percentage of the first metal in the product. If this is higher than is desired, a certain amount of scrap-iron can be added to the mixture of ore and carbon and charged in the furnace first, in order to obtain any other percentage desired, but there is a maximum possible depending upon the composition of the ores themselves.

We have thus obtained alloys containing from 5 to 7% of carbon (more or less), mostly, as we have said, in the graphitic state, and titanium in variable proportions from about 10% to 25%, or more.

For certain purposes the presence of carbon may prove objectionable, and we have made alloys containing but 0.18 to 0.70% of carbon, operating in the same furnace, by substituting aluminum for carbon as a reducer of the metallic oxides. This property of aluminum to reduce nearly all metallic oxides has been known for the last fifty years or more as a laboratory experiment. If aluminum in impalpable powder be mixed with finely-powdered oxides and the temperature raised in one point of the mass by means of a primer of magnesium, for instance, the reaction will proceed by contiguity of mass without the intervention of any external heat. A temperature estimated by some to be as high as 3,000° C. can thus be secured, and it has formed the basis of a special industry, the "aluminothermics," as it has been called in Europe. In such case the aluminum powder is mixed with oxides yielding their oxygen readily, the reduction of the oxides being but a means of securing the heat, and not the purpose of the operation. Dr. Goldschmidt, to whom the in-

dustrial realization of a well-known principle is due, has been able, with proper devices, to generate heat, in loco, sufficient to solder iron and steel castings, and to melt metals difficult to melt otherwise. Applied to the reduction of metallic oxides in order to obtain alloys, simple as the method appears, it becomes very expensive, as the aluminum in powder costs six or seven times as much as aluminum in ingot.

We have found that, instead of using aluminum in fine powder, all the reactions of aluminum in this state can be secured by a bath of aluminum brought to a proper temperature, such as is conveniently secured in an electric furnace, for instance.

If, then, in our furnace we charge aluminum, scrap, or ingot, melt it, charge the titaniferous iron ores, and in the bath the latter are readily reduced as they were before by carbon, and the heat generated by the oxidation of aluminum allows us to moderate considerably the current applied at a certain stage of the operation. We have thus obtained alloys practically free from carbon, while the aluminum, oxidized to alumina, formed with the gangs of the ores an aluminate which floated on and separated cleanly from the metallic molten mass of the alloy. This aluminate is harder than natural corundum, and can be used as an abrasive material, or it can be used as a source of alumina, the basis of the manufacture of aluminum. Alloys can be obtained in this manner at a much cheaper cost than with powdered aluminum, in the proportion of the cost of this metal in the two states, as the cost of the "external heat supplied" in this case is but an insignificant part of the total expense incurred. But we have used another process of manufacture, of which the economy is considerably greater.

From a titanic iron ore containing, for illustration's sake, 20% titanic acid (12% titanium) and 70% oxide of iron (say 50% iron), it is clear that, theoretically, we cannot obtain more than 12-62 = 19.35% titanium in the alloy, let the reducer be carbon or aluminum and the latter in powder or in ingots, and let the heat be supplied externally, or directly and internally by the oxidation of aluminum; but furthermore, the quantity of aluminum to be added to the ore (leaving aside all questions of heat) must be such, in order to secure the reduction of the oxide, as to satisfy the chemical equation: $Fe_2O_3 + Al_2 = Al_2O_3 + Fe_2$; that is, for every pound of oxide of iron (or say 7-10 of a pound of iron reduced) we must add, in round numbers, ¼-lb. of aluminum. Our only alternative would be, then, instead of titaniferous iron ores, which are not any more expensive than ordinary iron ores, to use pure titanic acid or oxide (TiO_2) Rutile, which occurs in nature not very abundantly, and costs, even when but comparatively free from iron, something like $350 to $450 a ton.

Our method consists, starting from the above titaniferous iron ore taken as an example, to mix it with only such quantity of charcoal as is necessary to reduce the oxides of iron, but not the titanic oxide, and submit the mixture to a current of a very low intensity, not sufficient to reduce the titanic oxide, realizing in our furnace a temperature but slightly higher than that secured in a blast furnace, having previously added to the mixture of carbon and ore a quantity of limestone, or preferably lime, capable of forming, with the titanic acid of the ore, a regular titanate slag.

We have thus obtained, as a by-product, all the iron of the ore in the form of a charcoal titanic pig possessing all the valuable properties of such pig iron and in which are found some silicon, sulphur, and phosphorus from the ores and a slag or concentrate of titanic acid, practically free from iron and containing practically all the titanic acid of the ores. Treated by carbon or aluminum, this concentrate theoretically would yield metallic titanium without iron, and with proper mixtures with scrap-iron, titanium alloys as high as might be desired. We have thus indirectly obtained from a titaniferous ore containing 12% of titanium, an alloy containing 75% of titanium.

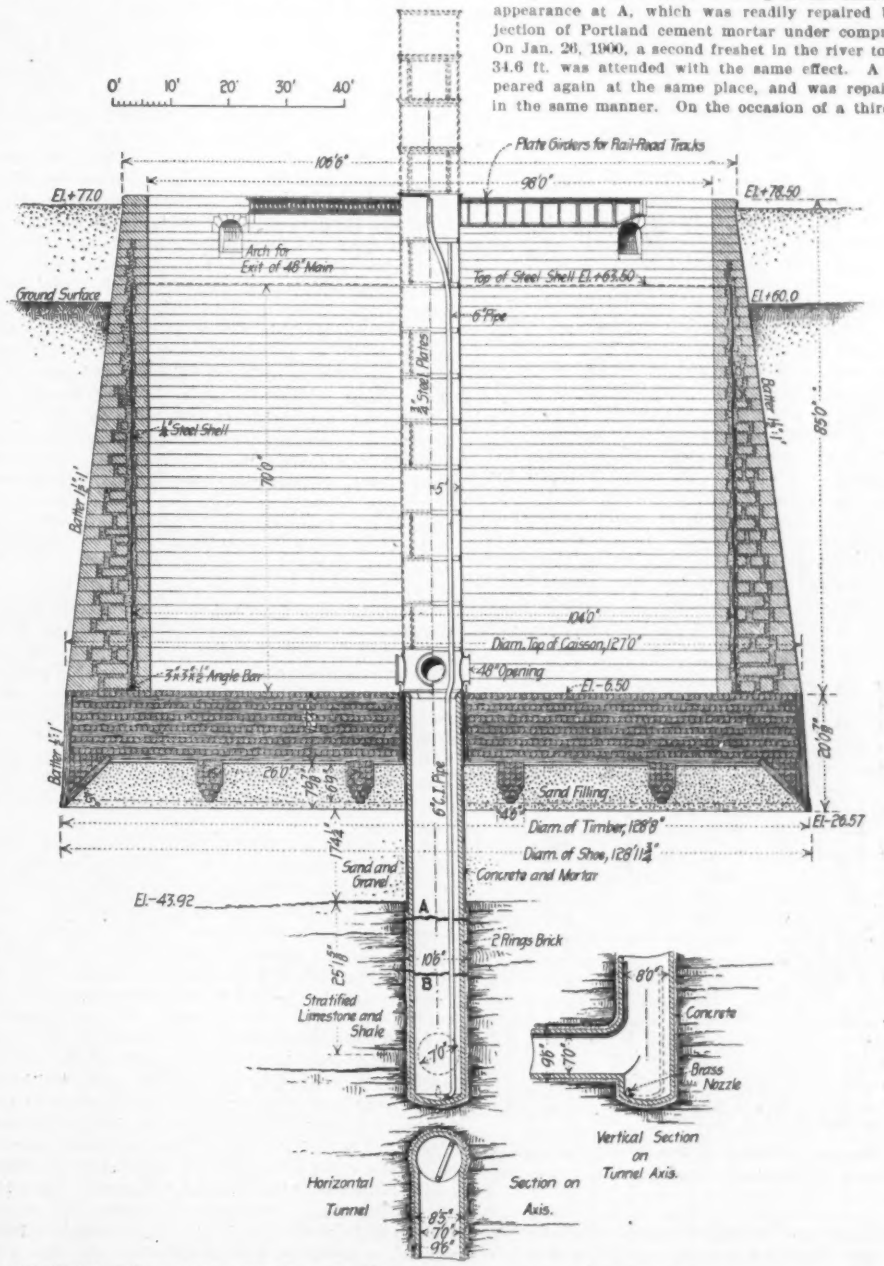
This concentrate not containing any oxide of iron practically, no aluminum needs be added on this score, and as this concentrate costs us nothing, all expenses to obtain it being covered and above by the value of the titanic pig obtained in the intermediary operation, the economy realized is considerable and in fact, alloys free from carbon, obtained by using aluminum as a reducer, by this method are but very little more expensive than those obtained from carbon itself.

But this concentrate has another application. Being practically free from iron, it can form the basis of the manufacture of alloys other than ferros. By using this concentrate as a basis and source of titanium, and charging copper scrap in a furnace instead of the ore, with the proper proportion of aluminum to reduce the titanic oxide of the concentrate, we have obtained alloys of titanium and copper, cupro-titanium, containing from 8 to 15% titanium.

Added to manganese bronze in a large construction establishment in the proportion of 4 lbs. of the alloy (10% Ti) to 100 lbs. bronze, the results were so satisfactory as to justify the protracted tests contemplated. The following results were observed on bars 0.759-in. diameter, area, ½ sq. in.; length, 2 ins. between clutches: Elastic limit, 25,200 lbs. per sq. in.; tensile strength, 63,080 lbs.; reduction area, 41.56%; elongation, 45%.

THE BREAK IN THE INTAKE CAISSON FOR THE NEW WATER-WORKS FOR CINCINNATI, O.

The appearance of two cracks in the masonry lining of the shaft which connects the pump-pit with the intake tunnel for the new water-works of Cincinnati, O., has recently been heralded with much adverse criticism by a portion of the newspaper press of that city. The construction of the new caisson pump pit, shaft and tunnel were fully described in our issue of Dec. 8, 1898, and in order that our readers may obtain a clear notion of the accident mentioned, and of the extent of the possible damage which may result from it, we reproduce from our issue of Dec. 8, 1898, the drawing



SECTION THROUGH PUMP PIT AND SHAFT, SHOWING LOCATION OF CRACKS IN SHAFT MASONRY; CINCINNATI, O., WATER-WORKS INTAKE.

showing the pump pit and tunnel, with the shaft connecting them, to which we have added lines showing the location of the cracks in the shaft masonry. This drawing, with the following explanation of the accident from Mr. G. Bouscaren, M. Am. Soc. C. E., the Chief Engineer of the new water-works, furnishes a reasonable and sufficient explanation of its cause and significance. Mr. Bouscaren's letter to us is as follows:

The pump-pit is on level ground, about 200 ft. from the top of the river bank and about 1,400 ft. from the channel where the intake pier is located. The caisson rests on clean sand saturated with water, the shoe being at an elevation about 15 ft. below the lowest point in the channel. The chambers of the caisson were filled with the same sharp sand in October, 1899, at a time when the river being low the air pressure required to keep water out of the working chambers was only about 15 lbs. per sq. in., which pressure was in a large measure counterbalanced by the weight of the sand ballast placed on the deck during the sinking process. The shaft connecting the pump-pit with the tunnel was sunk immediately after the chambers had been filled, the portion of the shaft between the caisson and the rock being a cylindrical steel shell, lined internally with concrete and brick in Portland cement, and the same lining extending through the rock to the tunnel. This brick lining was built in November and the beginning of December, 1899, also a period of low water. The first high water after the construction of the pit and shaft occurred on Dec. 26, 1899. It reached 25.2 ft. above datum. At the date mentioned an open seam in the brick lining of the shaft made its appearance at A, which was readily repaired by an injection of Portland cement mortar under compressed air. On Jan. 26, 1900, a second freshet in the river to elevation 34.6 ft. was attended with the same effect. A seam appeared again at the same place, and was repaired again in the same manner. On the occasion of a third rise, on Nov. 30, 1900, elevation 42.3 ft., the same thing occurred again, but this time the seam showed itself at B, about 10 ft. below the first crack at A. In the meantime levels taken on the deck of the caisson from time to time had shown a deflection upward coincident with each period of high water. These deflections were permanent, indicating that the sand had followed the roof of the chambers. It is quite evident that the open seams in the brick lining have been caused by the deflection of the caisson deck carrying with it the steel shell and part of the brickwork below it, and that the same phenomena will repeat itself with every stage of water higher than those preceding them since the execution of the work and until a sufficient weight has been placed on the deck to neutralize the effect of the highest water. For this reason it was decided not to repair the last crack until the pumping engines have been placed on the deck, as the weight of

these engines will be equivalent to that of 25 ft. of water in the pit, and as the last high water (elevation 50.6 ft.) was only 11.4 ft. below the highest water on record, we will then be secure against any further deflection of the deck. There is, in fact, no necessity for filling this crack other than the desirability of having a water-tight shaft on the rare occasions when the tunnel will be pumped out for examination.

INLET VALVES AND THEIR RELATION TO THE EFFICIENCY AND VOLUMETRIC CAPACITY OF AIR COMPRESSORS.

By Fred. Brainard Corey,* M. Am. Soc. M. E., Assoc. M. Am. Inst. Elec. E.

It is probable that no single part or group of parts of the modern air compressor has received so much consideration and been the subject of such careful experiment as the inlet valves and their operating mechanism. However, notwithstanding these facts, it is certain that there is no other portion of the machine in regard to which such differences of opinion exist at the present time. An examination of the various trade catalogues brings out the remarkable fact that in each single catalogue from one to six different forms of inlet valve and valve gear are shown in connection with machines that are supposed to represent the manufacturers' latest types. If any one type of valve were satisfactory in its operation and at the same time sufficiently simple in its construction, there would be no excuse, from an engineering standpoint, for this great multiplicity of types, even when the machines were designed for widely different operating conditions. It is a fact, however, that many of the valve mechanisms in use at present were designed not from considerations of economy or utility, but merely to conform to the ideas and prejudices of the purchaser or his advisers. It is the object of this paper to call attention to some of the peculiarities of inlet valves of the most usual types under various working conditions, in such manner as to aid the designer, as well as the prospective user, of air compressors in making an in-

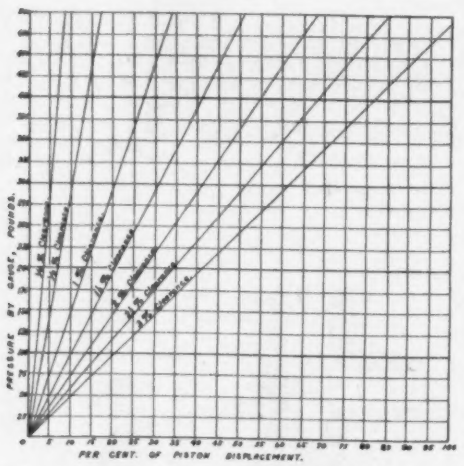


Fig. 1. Diagram Illustrating Effect of Clearance in Reducing Volumetric Capacity of Air Compressors.

telligent choice when called upon to decide what type of valve shall be used in any given case.

These various inlet valves may be divided into two general classes; first, those that are automatically opened by atmospheric pressure and closed by means of springs, weights or air pressure; and, second, those which are opened and closed by direct and positive mechanical connection with the crank shaft or some other moving part of the machine. Each of these classes has many representatives and the two combined include, I believe, all inlet valves now used on air compressors and blowing engines, with the exception of two special valves, one of which is located in the piston and operates from its own inertia, while the other is located in the cylinder head and is moved by frictional contact with the piston rod. Valves of the first class are entirely automatic in their action, their opening and closing points depending entirely upon the conditions of pressure within the cylinder. However, they have certain disadvantages which will be considered later. Valves of the second class, with one or two exceptions, which do not affect the questions considered in this paper, have their points of opening and closing fixed without regard to changes in operating conditions, and the present tendency among designers and manufacturers seems to be toward valves of this class. Many engineers are specifying mechanically operated valves for their compressors, with the idea that by so doing they will surely get the best possible machine for any purpose.

It may be well to note here that in trade catalogues the capacities given in the tables of sizes are the theoretical, rather than the actual, capacities of the compressors listed. Some builders claim to realize the full theoretical capacities of their machines and in support of their claims show indicator cards, taken from their machines, under actual working conditions, in which no volumetric loss can be detected. Such cards often show a compression line that conforms very closely to the isothermal when that theoretical line is plotted upon the card. Such highly satisfactory cards can only be obtained from compressors with mechanically operated valves and the increasing popularity of machines of this class is in some measure due to this cause. Nothing can be superior to these compressors when properly adjusted to their operating conditions, and several of the leading builders of this class of machinery have numerous plants in operation in which the inevitable losses are reduced to the practical minimum. On the other hand, there are hundreds of plants now operating in which faulty adjustment of valves, sometimes combined with improper design, render them extremely low in both efficiency and capacity. A careful study of these machines may be exceedingly profitable.

The engineer is accustomed to look upon the steam card as a true index of all that transpires within the cylinder; but if he imposes the same confidence in the card that is taken from the air end of the machine, he is liable to be led far astray. I believe that the inordinate claims made for many machines of this class are not because of any lack of moral integrity on the part of their builders, but because of failure to thoroughly analyze their valve motion in connection with the cards and to properly measure the volume of the intake air.

It is common to find inlet valves so set that they open almost exactly on center, with the result that the card indicates absolutely no clearance at either end of the cylinder, the clearance air being exhausted through the intake. If we suppose the inlet valve to close slightly before the piston reaches the end of its stroke, the amount of air taken into the cylinder is correspondingly reduced and it is evident that the compression curve will be displaced in a horizontal direction. The slight drop in the lower part of the curve will not be easily detected and the curve will have the appearance of very closely conforming to the isothermal line. Thus it is seen that an almost ideal card may be obtained from a compressor in which the valve adjustment is such as to seriously affect both the efficiency and volumetric capacity of the machine. However, supposing the valve motion to be perfect and all clearance to be eliminated, the theoretical capacity of the machine will still be unattainable because of the heat imparted to the air from the cylinder walls during that part of the stroke when the inlet valve is open. This loss of capacity from heating, during the intake stroke, is a matter that depends upon the design of the entire air cylinder rather than upon the particular type of valve selected. The effect of heating the air during this portion of the compressor cycle has evidently been neglected by the designers of several machines which are otherwise entirely satisfactory. In this connection it is important to remember that if a water jacketed cylinder is filled with highly heated and therefore rarefied air, the compression line will approach nearer to the theoretical curve for isothermal compression on account of the greater transfer of heat through the cylinder walls. The result is an apparent increase of efficiency as shown by the air card, while in reality there an enormous waste of power and loss of capa

In order that we may further study the a of the inlet valve, we will consider the effe the clearance spaces upon the performance of compressor. In machines now on the mar made by builders of high standing, the clear varies all the way from one-fifth of 1% to at 2% of the piston displacement. The first fi applies only to very large long stroke compres and the latter to the small short stroke mach which are now used in such great numbers. T the latter figure is very greatly exceeded in m of the low pressure machines used in chemi and metallurgical processes. The long stroke m chine is necessarily very expensive. It must of the duplex or cross-compound type, for t relative conditions of pressure in the steam a air cylinders are such as to render the long stro single machine a commercial impossibility. Co siderations of economy of first cost point nat rally to the high speed single compressor, and such a machine the percentage of clearance b

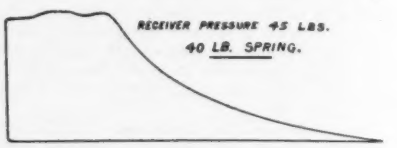


FIG. 2, ACTUAL CARD, VALVE OPENS ON CENTER.

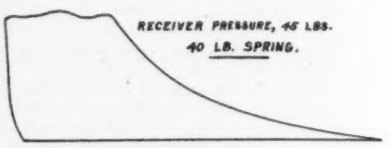


FIG. 3. SAME AS FIG. 2, WITH VALVES PROPERLY SET.

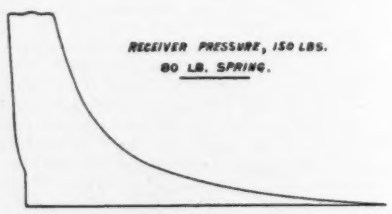


FIG. 4. SAME AS FIG. 3, WITH PRESSURE INCREASED.

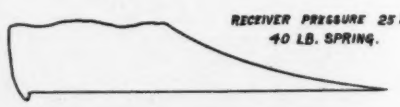


FIG. 5, SAME AS FIG. 3, WITH PRESSURE REDUCED.

Figs. 2 to 5. Indicator Diagrams from Air Compressors.

comes an important factor in determining its proper operation.

It is evident that the loss of capacity due to clearance varies with the pressure against which the machine is operating. Thus, if the cylinder has clearance spaces equal to 1% of the volume of the cylinder and is working against a pressure of six atmospheres (seven atmospheres absolute) the loss of capacity due to that clearance is 6%, and if the pressure is increased to ten atmospheres the loss is increased to 10% of the piston displacement. In case the inlet valves are so constructed that they cannot open until the clearance air has been expanded to atmospheric pressure, the only loss due to this clearance is one of capacity, which may be overcome by an increase in size or speed of piston. Figure 1 shows graphically the variation in the loss of capacity for different values of clearance and pressure. If, however, the inlet valve opens when the piston is in its extreme position, the clearance air is exhausted through the intake, making a direct loss

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of power as well as of capacity. Fig. 2 is reproduced from a card taken from a machine in which the inlet valves were set to open when the piston was exactly at the end of its stroke. There are very many compressors now in operation whose inlet valves are set in this manner. In most cases the exhaust through the intake is sufficient to cause considerable noise.

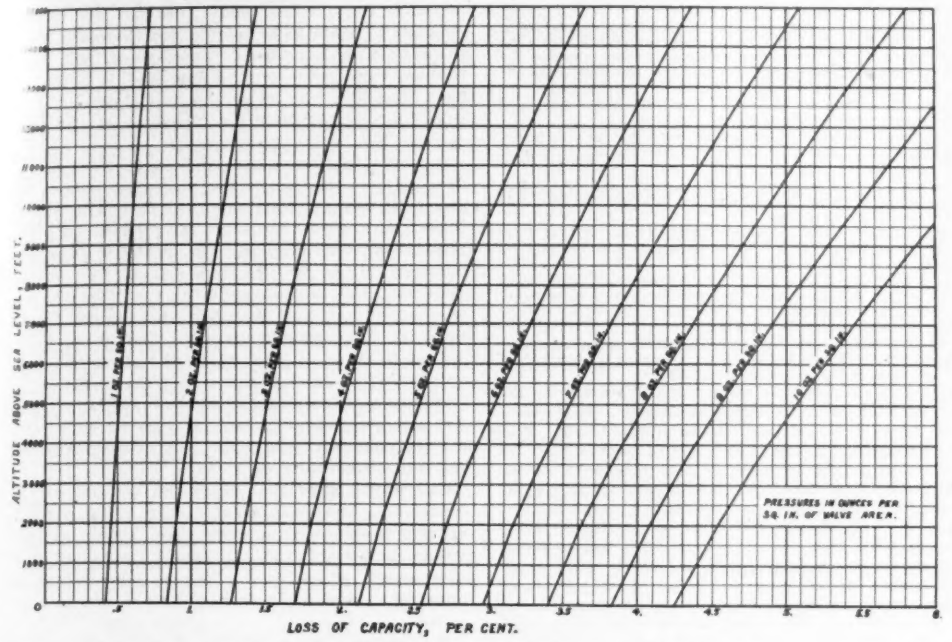


FIG. 6. DIAGRAM SHOWING REDUCTION IN AIR COMPRESSOR CAPACITY BY INLET VALVE SPRINGS OF VARIOUS PRESSURE.

Fig. 3 shows a card from the same machine, the valves having been properly adjusted for the pressure carried in this particular case. It should be noted that this adjustment affects only the point of opening and, therefore, the volume of air delivered is not changed, although the power required to drive the machine is perceptibly reduced and the machine runs more smoothly with less shock to its parts. If, after this adjustment, the pressure is increased, the former troubles again appear, the resulting card being shown in Fig. 4, in which case the receiver pressure has been increased to 150 lbs. per sq. in. If the pressure were to be continuously maintained at this point, a further adjustment in the same direction should be made. If, however, the pressure is reduced, the only effect is the slightly increased amount of power, represented on the card by the short bend below the atmospheric line, due to abnormal expansion of the clearance air, as shown in Fig. 5, where the receiver pressure is reduced to 25 lbs. per sq. in. The angles of these cards have been somewhat accentuated in order to show more clearly the effect of the changed conditions. In this discussion we have referred only to single-stage compression. It is evident that all losses due to clearance are greatly reduced in multiple-stage machines, as we then have to deal only with the pressure at which the air is discharged from the low-pressure or intake cylinder.

Every machine with mechanically operated valves should be carefully examined to determine whether or not the inlet valves close before the piston reaches the end of its stroke; and if such is the case the proper adjustment should be made to raise the output of the compressor to its maximum value. This adjustment should, if possible, be made independent of the indicator card.

In compressors using automatic valves, by far the greater part are furnished with those of the poppet type. In machines of this class the troubles shown in Figs. 2, 4 and 5 cannot possibly occur, as the valve action is entirely dependent upon the conditions of pressure within and without the cylinder. It is, therefore, evident that in these machines the clearance always results merely in a loss of capacity without the direct loss of power that may occur with mechanically operated valves. In these machines, however, there is a loss of capacity, as well as a slight loss of power, the latter usually negligible, due to the resistance of the valve springs. The spring pressure required for proper working varies from 3 oz. to 8 or 10 oz. per sq. in. of valve area, these differences of pressure being due to differences in design and construction of the valves themselves as well as to their condition resulting from care or neglect. Valves of this type should be as light as possible to reduce the effect of inertia and should be so designed as to be easily lubricated without danger of gumming. With careful attention to these details, a pressure of 3 oz. per sq. in. of valve area is ample, entailing a loss of but 1.2% in capacity at sea level, this loss being equal to the valve spring pressure in oz. per sq. in. of valve area divided by 7.85 times the barometer reading in inches of mercury. Fig. 6 shows by inspection the loss of capacity due to pressure on the inlet valves at sea level and at various altitudes.

Serious difficulty is sometimes experienced from slowness of action of the discharge valves. In case they become gummed or for any other reason they fail to act properly, the result is a decrease in the volume of air discharged. In machines with automatic inlet valves the principal direct loss from this cause is one of capacity, while in those whose opening point is fixed, the air flowing back into the cylinder will be discharged through the intake. While the latter means a serious loss of power, it furnishes a means for detecting improper action of the discharge valves which might otherwise go unnoticed.

A very important matter to be considered is the inlet valve area or port opening required for the proper action of the machine. Such wide differences exist in practice in the ratio between port opening and area of piston that the designer is almost led to believe that this is a matter of no special importance. We find many machines with a valve opening equal to only 3% of the piston area, while others are provided with an opening, the section of which is equal to nearly 14% of the cross-section of the cylinder. The internal surface of the cylinder, both barrel and heads, is mostly available for port openings or water jacketed cooling surface, and it is, therefore, evident that a loss in one direction may possibly be met by a gain in the other. The most economical division of this surface depends upon several variable functions and is a detail that should be very carefully considered in the design of a new machine. Fig. 7 is instructive as showing the reduction in density of the air within the cylinder for various percentages of valve area, based upon the assumption of constant piston speed with a coefficient of influx equal to 0.50.

In view of the above considerations, it would seem to be impossible to produce a single type of compressor valve gear that shall best meet all the conditions of both engineering and commercial feasibility, the case being in many respects analogous to that of the steam valve gear. A choice of valves should not be made in any important instance without thorough investigation of all the variable factors involved.

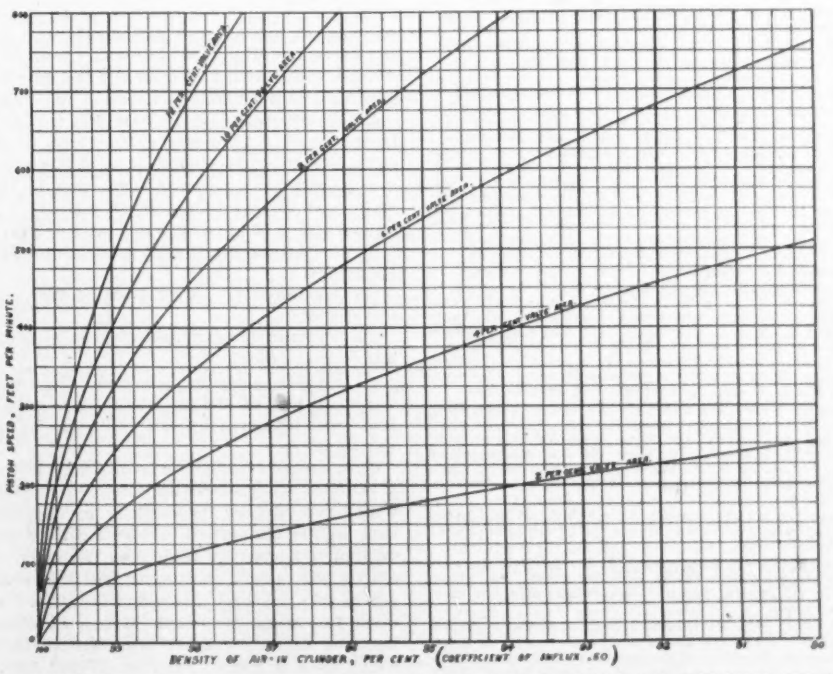


FIG. 7. DIAGRAMS SHOWING EFFECT OF REDUCED PORT OPENING ON DENSITY OF AIR IN THE CYLINDER.

THE UNION STATION at St. Paul, Minn., is to be enlarged and the track and yard system rearranged so as greatly to increase the capacity of the station. The width of the yards will be increased by filling in along the bank of the Mississippi River, which work is being done by the Butler & Ryan Co. The number of tracks in the trainshed will be increased from 9 to 14, and there will be 13,525 ft. of passenger tracks. There are about 370 train movements per day at this terminal. The new arrangement of the terminal has been designed by Mr. H. M. Sperry, of the Union Switch & Signal Co., and this company will install a complete signal and interlocking equipment.

RULES FOR A DRAWING OFFICE.*

By A. W. Robinson, M. Am. Soc. M. E.†

In June, 1894, the writer presented a paper to the Society, entitled "On the Relation of the Drawing Office to the Shop in Manufacturing," in which was given a set of rules which he then used in the drawing office under his charge. As improvement is always the order of the day, it became advisable to revise these rules, as suggested by experience, making them more concise and covering additional points as they arose. These revised rules are given below in the hope that they may prove useful.

DRAWING OFFICE RULES.

SIZE OF DRAWINGS.—(1) The standard size shall be 23 ins. × 36 ins., subdivided into half, quarter and eighth sheets.

(2) Full size drawings shall be reserved, as far as possible, for general views and parts not capable of being shown on smaller sheets.

(3) All shop detail shall, as far as possible, be shown on quarter and eighth sheets.

CHARACTER OF DRAWINGS.—(4) Detail drawings shall, as far as possible, classify the different kinds of works, such as castings, forgings, shafts, levers, piping, etc. Different kinds of work shall not be shown on the same detail drawing.

(5) All shop drawings liable to repetition shall be traced and blue-printed. All temporary details, requiring only one copy, may be made on sketch sheets and press-copied.

(6) A shop drawing is to be considered as an order or instruction to the shop, and not merely as a statement or illustration. For this purpose it must convey clearly and distinctly all the information necessary to make the article.

(7) Every dimension necessary to the execution of the work is to be clearly stated by figures on the drawing, so that no measurements need to be taken in the shop by scale. All measurements to be given with reference to the base or starting point from which the work should be laid out, and also with reference to center lines.

(8) All figured dimensions on drawings to be plain round vertical figures, not less than ⅛-in. high, and formed by a line of uniform width and sufficiently heavy to insure printing well. No thin, sloping or doubtful figures or diagonal-barred fractions will be tolerated. All figured dimensions below 2 ft. to be expressed in inches.

(9) All center lines to be alternate dot and dash in fine black line. All dimension lines to be double dot and dash, with a central space for the figure, and of such strength as to show on blue-print more faintly than lines of drawing. Lines of drawing to be bold and clearly defined in proportion to the scale, and may be shade-lined by making the right-hand and bottom lines heavier. No ornamental shading or other "frills" allowed on shop drawings.

(10) Every drawing, whether whole or half-sheet, shall have the title, date, scale and number of the sheet stamped in lower right-hand corner, and the quarter and eighth sheets printed on top.

(11) The name of the drawing, as given in the title, is invariably to consist of two divisions in one line separated by a hyphen. The first division is to state the general name of the thing or machine, and the second name is to clearly designate the part or parts represented (or if a general view should so state). The wording of titles should be submitted to the chief engineer or head draftsman for approval.

(12) Each drawing shall bear the name of the draftsman and examiner, the surname being used without initials.

(13) Drawings of piping details shall be made in diagram form, using standard symbols.

(14) All detail parts for standard or repetition work shall be shown unassembled as far as possible.

DRAWING SYMBOLS.—(15) Detail shop drawings should state: (a) the pattern number of every casting in plain figures of larger size than the dimension figures; (b) the material of which the parts are made, using symbols as follows: C.I. = cast iron; Bs. = brass; W.I. = wrought iron; Bbt. = babbitt; M.S. = machinery steel; Bz. = bronze; H.S. = hammered steel; C.R.S. = cold rolled steel. For other materials write full name. (c) Finished surfaces will be indicated by "f" written on the line or surface to be finished. When not so marked, it is understood that the part is to be left black or rough. In cases where finish might be presumed but not required, follow the figured dimensions by the word "cast," if a casting, and "rough," if a forging.

STANDARDS.—(16) The following standards shall be strictly adhered to as given in the tables noted: (1) Table of standard diameters of shafting and key seats. (2) Table of standard stock sizes of rounds. (3) Table of standard stock sizes of flat steel. (4) Table of standard clearance fits. (5) Table of standard symbols for notation of riveting. (6) Table of standard symbols for pipe fittings. Also such other standards as may be adopted from time to time.

NUMBERING OF DRAWINGS.—(17) Drawers and filing cases shall be numbered consecutively. Drawers shall contain 100 sheets each, and filing cases 200 sheets each, and to be fully indexed. Drawings shall be numbered by a number indicating both drawer number and serial number in the drawer, thus: 7604 is the fourth sheet in drawer 76, etc.

(18) Drawing numbers shall be checked off the index as required, and the index posted up in uniform handwriting by the clerk.

(19) Standard size drawings shall be kept in drawers and quarter and eighth sheets in filing cases. All drawings shall be indexed by an index sheet kept in each drawer or case.

CHECKING.—(20) All drawings must be approved before being traced. When tracing is completed it will be given immediately to the chief draftsman, who will have a preliminary print made and carefully checked before being used.

PATTERNS.—(21) All patterns shall bear the number of the drawing on which they are first detailed, followed by a serial letter according to the number of patterns on the drawing.

(22) Standard patterns used repeatedly and liable to be ordered from in repairs must not be changed. Other patterns may only be changed when absolutely necessary and by order. When so changed they will bear the original number and letter followed by A for the first change, B for the second change, and so on, thus: 4860 AB is the second change in pattern 4860 A.

SKETCH BOOKS.—(23) Each draftsman will be supplied with a sketch-book by the company, in which he shall make all his notes, calculations and data referring to his work, and under no circumstances shall notes of value be made on loose sheets. Each entry should invariably be commenced with the subject and date, and full notes made of data on which the calculations were based and the results obtained clearly stated. These books are to remain the property of the company.

IN GENERAL.—(24) Changes in drawings, sketches or order lists issued to the shop shall only be made when authorized by the chief engineer, or, in his absence, by the chief draftsman, and when so authorized shall be made by the order clerk.

(25) The names of all similar parts in order lists and drawings are to be uniform.

(26) Tracing must be kept in safe for blue-printing purposes only. Office copies of blue-prints must be used for references.

(27) No drawing, print or photograph shall be taken from office without permission. Violation of this rule may result in dismissal.

(28) Until further notice the office hours will be from 8 to 12, and from 1 to 5.30. Draftsmen will be paid by the hour for time actually worked.

(29) Draftsmen who have been in continuous employment of the company for a year or more will be entitled to ten days' vacation, with full pay. No other allowance for time lost will be allowed.

(30) Draftsmen will not be permitted under any circumstances to write letters in the company's name or on the company's letter-heads or envelopes.

It will be noticed that rules 2 and 3 provide for the restriction of the use of large drawings to general views, and increased use of small drawings for details. Formerly it was the custom to use only one size of sheet (23 ins. × 36 ins.) for all purposes. As time went on the multiplication of drawings made it difficult to provide house-room and drawer accommodation, and, furthermore, the large drawings were not so convenient in the shop as small ones. Resort was therefore had to eighth and quarter sheets, which were indexed in filing cases. This method results in a great number of small drawings, but numbers are cheap and the filing cases are easy to store on shelves, like books, and are practically self-indexing. An index card is placed in the front of each filing case, with lines numbered from 1 to 200, and as fast as drawings are put into it the numbers are checked off and the title written in. The ordinary Amberg transfer case is used. Forty of these filing cases do not take up much room, and they hold 8,000 drawings, part of which are 9 ins. × 11½ ins. and part 11½ ins. × 18 ins. All these tracings have the company name and title printed in blank with space for date, number, examiner's name, etc., so that uniformity is preserved.

*Abstract of a paper presented at the Milwaukee meeting (May, 1901) of the American Society of Mechanical Engineers.

†2 Weredale Park, Westmount, Montreal, Canada.

COEFFICIENT OF FRICTION IN DAM DESIGN, AND THE FAILURE OF THE DAM AT AUSTIN, TEX.

By H. P. Gillette,*

The failure of the "Austin dam" on April 7, 1900, has called forth about a score of letters to the various engineering periodicals, and now that the facts are fairly well known, it may be well to discuss the theories. Failure of the dam has been attributed by different writers to the following:

(1) Undermining of the dam due to: (a) A fault in the strata of limestone; (b) blows of water at the toe destroying a shell of hard stone overlying a soft stratum; (c) cave formation in the limestone due to solvent action of water.

(2) Impact of moving water and debris.

(3) Accumulation of drift on dam unduly raising the water.

(4) Accumulation of silt back of dam increasing the thrust.

(5) Vacuum formed under sheet of water flowing over the face.

(6) Finally, I desire to present the theory that the coefficient of sliding friction was actually less than was assumed by the engineers in designing the dam.

First let us consider undermining. If there was a fault in the rock under the dam it could in no wise have affected its stability by decreasing the load on the foundation, unless a direct connection existed between the fault and the body of water above the dam. Assuming such a connection, which has not been proved, the upward pressure upon the masonry would have been about 4,800 lbs. per sq. ft. of fault cross-section under the dam, with a water head of 77 ft.; but as the weight of a linear foot of the dam was not less than 308,000 lbs., it is evident that a fault a foot wide running lengthwise would reduce the load on the foundation less than 2%, which the factor of safety far more than covered. An opening of any such size could not have existed unobserved. It may still be argued that even from a smaller fault a thin stream of water would find [illegible] underneath the whole foundation, but [illegible] equivalent to assuming that the mortar [illegible] form a close connection with the foundation. Even without any inspection at all such a [illegible] tion is by no means probable; indeed it is [illegible] tically impossible.

The existence of a cave under the dam has been proven, while soundings taken by Prof. [illegible] lor since the accident show that no cave of [illegible] magnitude could have existed. Furthermore, the cave must have been formed since 1890, [illegible] borings were made on the dam site, it is [illegible] bent upon him who offers the cave theory to [illegible] that fresh water dissolves limestone at any [illegible] rate as his theory pre-supposes.

It is stated that a man fishing in front of the dam prior to its destruction was able to shove his pole back several feet under the dam, and, therefore, it is argued that since the friction upon the foundation was reduced, due to relief from the pressure on the toe, the dam failed. This theory does not take into account the fact that the toe was still intact, and, together with the rest of the masonry, was bearing upon the rest of the foundation back of it, and must therefore have required no less force to move it, if the coefficient of friction is a constant. Furthermore, if failure was due solely to undermining by working back from the toe, the dam would have overturned and not slid out horizontally as it did.

One writer says that since the velocity at the center of a stream is greater than at the sides, a greater pressure must exist upon a dam at that point. It would be well if those formulating theories would endeavor to express themselves in numbers occasionally rather than in words altogether.

If a current has a velocity of 12 ft. per sec., or eight miles an hour, the "head due to the velocity" will be 2¼ ft., and even assuming a pressure due to such a head over the whole back of the dam, the total pressure would be about 9,000 lbs. per lin. ft of dam, or only 5% of the pressure due to static head. Furthermore, it may well be questioned whether the body of water below the crest of the dam has any appreciable horizontal velocity that can affect the rear of the dam at all.

Eye witnesses state and photographs show that the amount of debris striking the dam was immaterial, and even had it been great, the blows would probably have caused overturning rather than sliding, because of the great lever arm of the pressure due to impact at the crest.

Accumulated drift did not raise the water level as some have supposed; in fact, the level of the water above the crest just before failure was 11 ft., whereas the dam had been designed to resist a level 4 ft. higher still.

As for accumulated silt back of the dam, that could not have appreciably increased the total pressure on the rear of the dam. It would probably act to reduce the total pressure; for, according to the generally accepted theory of earth pressure, $H = 19\ h^2$, when the slope of repose is 2 to 1. Even at 4 to 1 the pressure is less than for water, which is $H = 31¼\ h^2$, in which H = total horizontal thrust of earth or water on a linear foot of wall, in pounds, and h = depth in feet, or head of water or earth. According to the commonly accepted theory of earth thrust, the unit pressure is the ordinate of a straight line wherein the abscissa is the head or depth of earth. The writer will later present theoretical and experimental proof showing that the pressure curve is a parabola and not a straight line, and that the thrust of liquid mud is less than water when the depth is over 25 ft., as it was back of the Austin dam.

Prof. G. S. Williams, of Cornell University, has presented an ingenious theory, namely, that the sheet of water flowing over a dam with a curved profile produces a vacuum between the water sheet and the dam, and states that in a model dam 8 ft. high, with water 2 ft. over crest, a reduction of atmospheric pressure of 1-6 atmosphere (= 2½ lbs. per sq. in.), has been produced near the toe of the dam. He argues that in a large dam this might become a pressure of 12 lbs. per sq. in. The last statement is a mere assumption, which he makes no effort to prove.

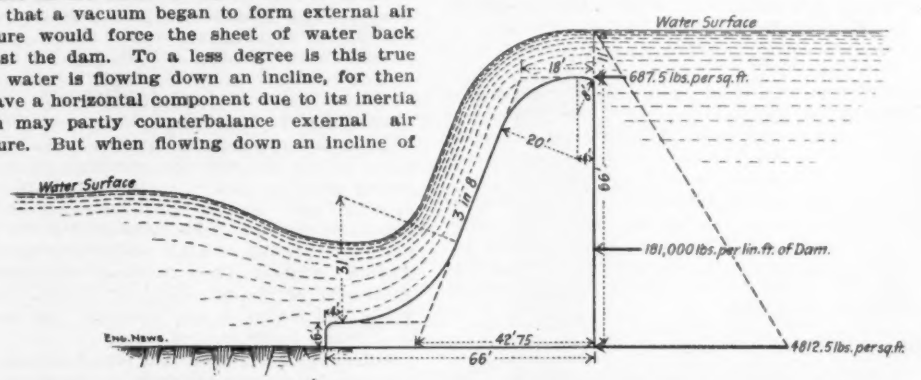
A pressure of 2½ lbs. per sq. in. all over the rear

*751 Powers Block, Rochester, N. Y.

of the dam would be nearly 24,000 lbs. per lin. ft. of dam 66 ft. high, or an amount equal to about 13% of the actual water pressure, and certainly covered by the factor of safety; but Mr. Williams explicitly states that the vacuum is produced only at or near the toe, and even assuming an absolute vacuum (14¾ lbs. per sq. in.) for a height of 11 ft. above the toe the effect to produce sliding would be no greater than a pressure 1-6 atmosphere over the whole height; in other words, an effect equal to only 13% of the water pressure. This pressure would be sufficient to cause failure if the actual factor of safety were only 1½, but as dams are usually designed it would not be the sole cause of failure.

In the mind of the writer there is grave doubt as to the existence of any vacuum near the toe of the Austin dam at the moment of failure, because the seething mass of water, some 25 to 35 ft. deep at the toe, would not be as favorable a condition for the formation of a vacuum as a 2-ft. sheet of water flowing over an 8-ft. model; and it must be remembered that even a partial vacuum could not possibly form unless the water were flowing continuously away from the face of the dam.

Where a sheet of water is falling vertically down the face of a dam, practically no vacuum could exist between the sheet and the dam, for there would be nothing to resist the external air pressure on the water sheet, and at the very instant that a vacuum began to form external air pressure would force the sheet of water back against the dam. To a less degree is this true when water is flowing down an incline, for then we have a horizontal component due to its inertia which may partly counterbalance external air pressure. But when flowing down an incline of 3 in 8, as on the Austin dam, the vertical component is greater than the horizontal component, and this being so, a vacuum on that portion of the dam would be mechanically impossible, for there would be a greater force holding the water against the masonry than the force tending to carry it away from the masonry. However viewed, the vacuum theory is in this instance not satisfactory.



CROSS-SECTION OF AUSTIN DAM WITH ASSUMED CONDITIONS OF FLOW AT TIME OF FAILURE.

(Cross-sectional area, nearly 2,200 sq. ft. Weight of dam, per lin. ft., 308,000 to 330,000 lbs.)

We have considered all the various theories thus far presented, and not one nor any combination of them offers a satisfactory explanation of the failure of the Austin dam. I now desire to present a theory that is founded upon no assumptions of conditions that may or may not have existed, such as caves, or vacuum. The dam slid out. Obviously the friction between the dam and its foundation, or between some underlying strata was not equal to the water pressure. Herewith is a cross-section of the dam showing the height of water at the time of failure. The pressure at the crest of the dam was 687.5 lbs. per sq. ft., and at the base 4,812.5 lbs. per sq. ft., thus developing a total horizontal thrust of 181,500 lbs. per lineal ft. of dam.

The area of cross-section of dam masonry was about 2,200 sq. ft.

Assuming the weight of masonry at 140 lbs. per cu. ft., the total weight per lin. ft. was 308,000 lbs., or if the masonry weighed 150 lbs. per cu. ft., the weight of a lineal ft. of dam was 330,000 lbs. As a probable and fair average, we shall assume 320,000 lbs.* Besides the weight of the masonry, there was the weight of a sheet of water over the crest 11 ft. thick by 18 ft. long, equivalent to 1,300 lbs. per lin. ft. of dam; a sheet of water on the face down to the lower curve 11 ft. thick and about 40 ft. long, which, although not bearing directly upon the dam, we shall assume to do so, and therefore equivalent to 2,700 lbs. per lin. ft. Over the projecting curved toe the average depth was not to exceed 20 ft. by 30 ft. long, equivalent to 37,000 lbs. per lin. ft., and making a grand total of about 360,000 lbs. per lin. ft. vertical load on the foundation.

The horizontal thrust of the water at the rear of the dam was not less than 181,500 lbs. per lin. ft. Therefore, the dam would have failed if the coefficient of sliding friction was less than 0.5, provided there was no counter thrust from the water in front of the dam.

One observer says that the fall of water was about 40 ft., which would have meant an effective counter pressure due to 37 ft. of water. Photographs taken just before and just after the failure indicate a depth of water up to or just below the beginning of the tangent on the face, which would mean a depth of water of about 26 ft. in the lower river.†

Assuming first a depth of 37 ft., we find from the formula $H = 31¼\ h^2$ that H = 42,800 lbs., which, subtracted from 181,500, leaves 138,700 lbs., under which condition the dam would fail by sliding if the coefficient of friction was less than 0.38.

Assuming that h = 26 ft., then H = 21,100 lbs., and the effective thrust was 181,500 — 21,100, = 160,400 lbs., and the dam would fail if the coefficient of friction was less than 0.44.

In support of the first supposition that there was no effective back pressure of water on the front of the dam, it may be argued that due to its great momentum the sheet of water flowing down the face would push the water below away from the face, producing an effect shown in the section. That this occurs in ogee dams is a well-known fact; but although this phenomenon should receive consideration in dam design we are not dependent upon its occurrence to account for the failure of the Austin dam. It is admitted that the toe of the dam was somewhat undermined; therefore there could have been no resistance except friction, cohesion between strata, and tensile strength to prevent sliding of the stratum of limestone forming the foundation.

The existence of a fault under the dam is vouched for both by a geologist and by engineers; therefore tensile strength could not prevent sliding of the stratum. Cohesion between strata must have been exceedingly slight when, as is stated, there existed a stratum of soft material that did not even require a pick to loosen. It is well known to quarrymen that even in beds of limestone and sandstone that are themselves very solid and strong, the cohesion between adjoining beds is often practically nil; in other words, after cracking a bed vertically it requires only sufficient force to overcome friction to move it horizontally if there is a free face in front. The question then resolves itself to this: "What is the coefficient of friction between smooth surfaces of stone?" Fanning (quoting Morin) gives it as low as 0.38 for limestone on limestone and 0.33 for stone on wet clay, and parenthetically, we may add, the soft material between limestone layers is quite as unctuous as any clay. Trautwine gives the coefficient of sawed limestone dry on same = 0.4, and beds of stratified rock often have faces as smooth as sawed stone.

In designing dams, Fanning states that a coefficient of friction of 0.62 between the masonry and its foundation may be assumed, and says a factor of safety of 1.5 is ample, thus reducing the safe working coefficient of friction to 0.41. But we have seen that under no assumption could the thrust have been much less than 0.38 of the vertical load, so that failure was certain to have occurred if the coefficient was less than 0.38; yet the dam was undoubtedly designed upon the assumption that such a coefficient was safe, for we are told that a depth of 15 ft. over the crest was anticipated by the designers, which would mean a thrust 12% greater than it actually was at the time of failure!

In view of the fact that part of the limestone foundation stratum did actually go out with the dam, there is not the slightest doubt in the writer's mind that failure was due to no other cause than the use of too low a working coefficient of friction by the designers.

When a factor of safety of 2 or 3 is employed in providing against overturning, why have engineers been satisfied with a factor of safety against sliding of 1½ or less? Doubtless there can be but one reply, namely, that friction is assisted by cohesion, and even if it were not, the coefficient of friction is so well known that one can work closer to the limit. We have seen that in the Austin dam, and indeed in any dam resting upon stratified stone, little or no dependence can be placed upon cohesion between layers, or even upon tensile strength where vertical seams exist.

Finally, is the coefficient of friction between stone a well-known constant? In a dam 66 ft. high, where the pressure on the foundation was not less than 7,000 lbs. per sq. ft., is the coefficient of friction the same as for small blocks of stone, used by Morin and others in determining the coefficients used? It is a well-known fact that the coefficient of journal friction is by no means a constant during motion; indeed, it decreases rapidly with increased pressure, as Professor Thurston and A. M. Wellington have shown. While we will grant that the coefficient of starting friction between iron surfaces increases as the cube root or fourth root of the pressure, who can say that an entirely different law does not apply to stone?

While I am inclined to think that the coefficient of masonry friction does increase with the pressure, and while failure of the Austin dam is accounted for, even if there were quite an appreciable increase, still it seems nothing less than folly to allow only a factor of safety of 1½ where the exact value is so problematical.

Summarizing our argument, we conclude: (1) None of the various theories hitherto presented explaining the failure of the Austin dam are in themselves a complete and satisfactory explanation.

(2) There may be an absence or reduction of the back pressure below a dam due to the inertia of the moving sheet of water, and this should receive further experimental and theoretical attention.

(3) No other theory is necessary to account for failure than the one assuming absence of cohesion in the foundation stratum, due to its stratified form and a vertical seam; for under these conditions the coefficient of sliding friction of smooth strata is too low to resist the thrust that actually existed.

(4) Until extensive experiments shall have been made—and they should be made at once—a factor of safety of 1½ against sliding on foundations, giving a working coefficient of friction of 0.4, is too small in view of the unknown value of the coefficient of sliding friction under varying unit pressures upon varying materials.

*Since this article was written the writer has read Bulletin No. 40 of the U. S. Geological Survey, wherein Prof. T. U. Taylor states that the masonry weighed not over 125 lbs. per cu. ft., but as this discussion is not materially affected by so slight a difference from the assumptions already made the figures given herein have not been changed.

†Professor Taylor has recently stated that the lower river level was 38 ft. below the dam's crest at the time of the failure.

SIX YEARS OF SLOW SAND WATER FILTRATION AT MOUNT VERNON, N. Y.

Only those who closely follow the progress in water purification are aware of the existence of a slow sand water filtration plant at Mount Vernon, N. Y., modeled closely after the one at Lawrence, Mass., and put in operation less than a year after its model. Fewer yet know that careful records have been kept of the operations of the Mount Vernon purification works.

Through the courtesy of Mr. C. D. Turney, Manager of the New York Suburban Water Co., and with the aid of both Mr. Turney and Mr. A. H. Kneen, Engineer of the company, we are able to present a summary of the records just named, and also details of the methods of operation at Mount Vernon. Some general statements relating to the water supply of Mount Vernon and the design of the filters are given in an editorial on another page, in which there are presented some comparisons between the filter plants at Lawrence, Mass., Albany and Mount Vernon, N. Y.

DETAILS OF OPERATION.

The operations of the Mount Vernon filters for the last six years are shown in detail by Tables I. and II., taken from the books of the water company. Table I. is an itemized statement of gross yearly expenditures on account of filtration. Table II. gives for each year the water consumption, the extent and cost of scraping up and wheeling off, washing and replacing the sand, the cost of removing ice, and the average cost of filtration per 1,000,000 gallons. An examination of Table I. will show some variations, by years, in the manner of recording the cost of scraping, washing and replacing the sand. These appear to be due to a failure, in 1895-6, to keep the items separate, while in 1900 the variation seems to have been caused by the complete renovation of the sand, thus combining one scraping and the yearly washing and replacing of the sand in practically one operation.

The amount of water filtered has ranged from 1,350,000 to a little under 2,000,000 gallons per day, in 1895 and 1899, respectively. Messrs. Turney and Kneen state that the pumpage previously reported for the years 1897 to 1899 was excessive, owing to lack of allowance for slippage, which was found to be considerable. This and the unit figures in Table II., have been corrected accordingly. The pumps have been overhauled, and a further reduction in pumpage was made, in 1900, by the stoppage of leaks and the addition of meters. The maximum average daily pumpage was equal to a continuous daily rate of about 1,800,000 gallons an acre of filtration area, for the year 1899.

The cost of filtration steadily increased from the start (barring a very slight reduction in 1896), mounting up from $2.01 per 1,000,000 gallons in 1895 to $4.46 in 1899. This high figure was due partly to the unusual cost of ice removal in 1899, but is believed that it was largely due to the condition of the filter beds, since the cost was materially reduced in 1900, notwithstanding the extra expense for renovating the beds, and the fact that the renovation was not effected until the year was well advanced. No allowance for wash water is included in the figures. It is estimated that a total of about 15,000,000 gallons per year is used for that purpose. The water flows to the filters by gravity, but the elevation of the water in the clear water well is only a few feet below that in the adjoining reservoir. It would be possible, however, to deliver the water at an elevation some 30 ft. above the clear water well, provided the water was not sent to the reservoir first. It is believed that the slight extra lift is more than compensated for by the diminished wear of filtered water on the pumps, as compared with unfiltered.

The cost of superintendence, except on the part of the general manager, is included in the figures given. Nothing is included for the care of the banks of the filter beds, above the riprap, all such expense being included with the items pertaining to the care of grounds at the pumping station. In classifying the expense, scraping includes wheeling the sand out of the beds, up the rather high bank, and dumping it in a pile near the washer, at one side of the filtration area. Washing includes the dumping of the clean sand down the bank, directly below the washer. Replacing the sand covers the wheeling of the sand from the dump just named to the bed, spreading and shaping it.

The removal of ice is facilitated by the fact that for two of the beds it can be floated through a sluice gate into and down a channel. From the third bed, the ice is lifted over the division bank onto one of the other beds, and then floated off, as stated. It has been found that the exhaust steam from the pumping station, if turned into the water on the beds, will keep about a third of one bed clear of ice. This has suggested a system of steam piping over the beds for the application of steam to be used in getting rid of ice.

SCRAPING THE BEDS.

The men who work on the beds wear wooden sandals, or pieces of boards larger than their shoes, tied to their feet. The scraping is done by means of shovels. Steel wheelbarrows and movable plank runways are used.

Table III., kindly worked up by Mr. Kneen for inclusion in this article, shows the dates of scraping, and both number of days and quantities between scraping, for the last three years and four months. Other figures relating to scraping are given in Table II.

SAND WASHERS AND WASHING.

The dirty sand is washed but once a year. The work is done in the spring, not from choice, but because water can be spared best at that time. The original scheme for washing the sand, as described in our issue of Aug. 23, 1894, provided for a portable flume, extending over the bed, leading to a flume built in the division banks. The dirty sand was to be shoveled into the portable flume and conveyed by water from a hose through both flumes to one side of the filtration area. It was expected that the sand would be cleansed in its passage through the flume. This plan seems never to have been put in operation, for Tables I. and II. show no entries for washing sand in 1895 or 1896, and the published report of the company for the year 1897 contains a construction charge of $283 for a sand washer, erected during that year. This washer is similar to those at Lawrence, Mass., and Albany, N. Y. There are four cast-iron hoppers, with ejectors in their bottoms for lifting the sand, spouts for its discharge into the next hopper, and finally into the box for clean sand, and waste channels for removing the dirty water. The supply pipe from the pumping station is 2 ins. in diameter and the feed pipes to each ejector are 1½ ins. in diameter. The jets have diameters of 9-32-in. The jet special terminates in a 3 × 3 × 2 × 2-in. cross, into the opposite end of which is screwed a 3 to 1¼-in. reducer, small end down, which also connects with the vertical discharge pipe leading to the next hopper. The dirty sand is thrown onto and falls through a wire screen, placed over the first hopper. The clean sand is dumped from the receiving box down the bank to the edge of one of the filter beds. A second washer was added in 1900. It is practically a duplicate of the old one, except that it has rectangular wooden hoppers, instead of round cast-iron ones, and 10-32-in. jets in place of 9-32-in.

In 1900, the sand was removed down to the gravel, for the first time since construction, washed and replaced. Enough sand was added to make up for not only the scrapings of the preceding year, but also to increase the total thickness by 6 ins. Settlement to the extent of 2 ins. followed. This was being made good at the washing and replacing of sand, which was being carried on last week, when the plant was visited by a member of the editorial staff of this journal. When the old sand was removed, last year, it was found badly packed.

Experience has shown that one of the chief advantages of ridging the beds is the opportunity thus afforded for the escape of air in filling from above, after the filter has been cleaned. It also facilitates the resurfacing of the beds after renewing the sand, since by using a template they may readily be brought to shape in sections.

RESULTS OF FILTRATION.

Chemical analyses are made about once a month by Dr. E. J. Lederle, of the New York Health Department. Bacterial analyses were made formerly, but Mr. Turney states the results were so good that the bacterial analyses have been discontinued. As we understand it, the water is not polluted by the sewage of any municipality. The drainage area, however, would appear to be somewhat closely built up for a water gathering ground, judging from its proximity to New York. Unfortunately no analyses of the water before and after purification could be secured. It appears that the only samples collected regularly are from the taps in the city. Table IV. shows some analyses of filtered water. As we understand the letter which accompanied the analyses, they are averages of one analysis a month for a number of successive years, not always the same. During the past six months turbidity records have been kept, but they have not been tabulated.

TABLE III.—Dates, Days and Quantities between Cleaning Slow Sand Filters at Mount Vernon, N. Y., 1898, to April 28, 1901.

	Bet. cleanings— Days.	Million galls.		Bet. cl— Days.
1898.			1899.	
Jan. 22	22	39	Aug. 9.	13
Feb. 17	26	46	Sept. 3.	25
March 15	26	46	Sept. 28	25
April 10	26	45	Oct. 14.	16
April 25	15	28	Nov. 1	18
June 1	37	65	Nov. 17	16
July 6	35	72	Dec. 14	27
July 25	19	38	1900.	
Sept. 3	40	77	Jan 7.	24
Sept. 15	12	23	Jan. 18.	11
Sept. 27.	12	25	Feb. 11	24
Oct. 23	26	50	March 17	34
Nov. 8.	16	31	March 30	13
Dec. 2	24	46	April 15	15
Dec. 23	21	41	June 7	53
1899.			July 7	30
Jan. 14	22	42	July 27	20
Feb. 5	22	45	Aug. 30.	34
Feb. 24	19	39	Oct. 17.	48
March 3	7	14	Nov. 13	27
April 1	29	52	Dec. 16	33
May 2	31	63	1901.	
May 25	23	46	Jan. 1.	15
June 16.	22	48	Jan. 24	23
July 5	19	40	March 9	44
July 27	22	46	April 28.	50

TABLE I.—Itemized Yearly Maintenance Expenses for the Slow Sand Filters at Mount Vernon, N. Y.

	1895.	1896.	1897.	1898.	1899.†	1900.
Cleaning and renewing beds	$980	$1,151	.....	.....	.....	$893
Cleaning beds	...	.....	$876	$1,266	.....	.....
Overh'ling sand bed*	...	.....	.....	.....	.....	971
Cost of new sand	3	.....	.....	.....	.....	100
Washing sand	...	.....	322	342	.....	512
Placing sand on beds	...	.....	336	339	.....	.....
Removing ice	...	21	133	289	590	145
Miscellaneous	8	37	34	29	.....	68
Total	$991	$1,209	$1,701	$2,265	$3,228	$2,749

*Removing sand down to gravel, washing and replacing.
†The costs for 1899, except the total and the item for removing ice, were not reported to us by the company.

TABLE II.—Water Consumption at Mount Vernon, N. Y., and Detail Operations Slow Sand Filter Plant, 1895-1900.

	1895.	1896.	1897.	1898.	1899.	1900.*
Consumption, gallons: Total (millions)	493.3	607.6	646.1	686.0	720.5	679.4
Cleaning beds: Times per year	.....	8⅓	15	16⅔	16⅔	13⅓
Aggregate area cleaned, sq. ft.	.....	399,100†	618,370	708,190	782,236	638,500
Average cost: Per cleaning	.....	$95.39	$58.41	$75.95	$89.66	$66.95
Per 1,000 sq. ft.	.....	$1.99	$1.42	$1.62	$1.68	$1.39
Per 1,000,000 gallons	.....	$1.31	$1.36	$1.85	$1.81	$1.31
Washing sand: Amount, cu. yds.	.....	.....	1,036	1,133	1,524	1,627
Average cost, per cu. yd.	.....	.....	$0.32	$0.30	$0.27½	$0.31½
Replacing sand: Amount, cu. yds.	.....	518‡	1,036	1,133	1,664	1,842
Average cost, per cu. yd.	.....	$0.80	$0.32	$0.30	$0.31	$0.52
Average total cost, per cu. yd.§	.....	.....	$0.65	$0.60	$0.51	$0.81
Removing ice: Cost per year	.....	$21.00	$133.00	$289.00	$590.00	$145.00
Average cost of filtration, per 1,000,000 gallons	$2.01	$1.90	$2.46	$3.30	$4.46	$4.05

*Computed from the total cost of filtration for the year, Table I., and the cost per 1,000,000 gallons, in this table.
†The combined area of the three beds is 47,892 sq. ft.
‡New sand added? §Washing and replacing sand?

TABLE IV.—Average Analyses of Filtered Water Supplied to Mount Vernon, N. Y.

	February.	April.	May.	August.	Septemb'r.	October.
Appearance	Clear.	Clear.	Clear.	Clear.	Slightly turbid.	Clear.
Sediment	None.	None.	None.	None.	None.	None.
Color	Faint yel. brown.	Faint yel. brown.	Very faint brown.	None.	Light yel. brown.	Faint yel. brown.
Odor (heated to 100° F.)	Woody.	Sl.mrshy.	Sl. vgtble.	Sl.mrshy.	Marshy.	Marshy.
Chlorine in chlorides	1.28	0.780	0.643	0.99	0.693	0.633
Equivalent to sodium chloride	2.12	1.300	1.062	1.63	1.144	1.046
Phosphates	None.	None.	None.	None.	None.	None.
Nitrogen in nitrites.	None.	None.	None.	None.	None.	None.
Nitrogen in nitrates	0.1225	0.0047	0.0634	0.0593	0.0132	0.0605
Free ammonia	0.0075	0.0015	0.0030	0.0030	0.0015	0.0015
Albuminoid ammonia	0.0067	0.0030	0.0140	0.0030	0.0020	0.0035
Total nitrogen	.....	.....	0.0774	.....	.....	.....
Hardness equivalent to carbonate of lime:						
Before boiling	6.19	6.73	5.50	4.87	7.60	7.50
After boiling	6.19	5.35	5.50	3.98	7.60	7.50
Organic and volatile (loss on ignition)	3.10	2.50	3.00	2.50	2.70	3.50
Mineral matter (non-volatile)	13.00	9.80	7.50	5.40	7.90	7.00
Total solids (by evaporation)	16.10	12.30	10.50	7.90	10.60	10.50

As we stated in our original description of this plant, the cost of construction could not be made public at that time. Since then the works have changed hands, but the records transferred to the new management are said to have been very meager. It is understood, however, that the first cost of the filter beds was about $25,000. It does not appear that any material additions have been made to the construction charges since 1894, the chief items seeming to be the sand washer and the 6 ins. increase in depth of filter sand. This last, on an area of 47,892 sq. ft., would amount to 887 cu. yds.

A NEW CONNECTING ROD END.*

By C. W. Hunt, M. Am. Soc. M. E.†

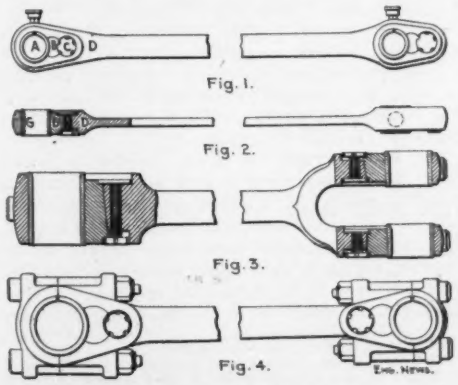
The adjustable bearings in a connecting rod are the most troublesome to fit up of any used in steam machinery. The stresses alternate so rapidly that any looseness in the parts of the bearings is followed by such violent shocks to the mechanism that the most rigid construction is required to prevent serious injury.

The method of construction, necessarily used from the peculiarities of the ordinary designs, requires the work to be done on slotting, shaping or other machines that must be manipulated by a skillful workman. These machines are not fitted to do rapid or duplicate work, nor is it convenient or even possible in many cases to obtain workmen having the requisite skill to make a bearing with the accuracy that the maker sets up for his standard.

In an effort to make a design which will require less minute measurements and highly trained personal skill, I have arranged the method of taking up the wear in a connecting rod or other bearing, which is illustrated in the cuts herewith shown. The work is done on machines which with ordinary attendance lend themselves admirably to duplicate work and accurate results.

The sides of the rod are planed off, and the ends turned or milled to bring the exterior to the finished shape shown in Fig. 1, or bolted rigidly together in Fig. 4.

A hole for the wedge B is then drilled and reamed at an inclination with the axis of the crankpin of about one in ten. In this hole the cylindrical plug B is inserted. It is made an easy sliding fit, but is temporarily



Figs. 1 to 4. Elevations and Sections Showing Construction of a New Form of Connecting Rod End.

held fast during the following manipulations by a wedge key or other means, while the hole for the crankpin bushing G is bored at right angles to the axis of the rod. Both holes are cylindrical, but their angle to each other makes B a wedge, convex on the rod side and concave on the bearing side. The holding key is now removed, and B is free to move any distance in the direction of its axis, but if it is moved endwise it will throw the concave side towards or from the crankpin A. To adjust and hold B in position a screw C is fitted with two collars to embrace the ends of the wedge. This screw may be fitted wrench-tight to hold it securely in any position, or it may be held by other means in large bearings.

To illustrate the delicacy of adjustment, we may assume that the axis of B is at an inclination to the crankpin of one in ten, the screw C cut with 20 threads to the inch, and the head slotted with five notches 72° apart, then the revolution of the screw C one notch will move B 1-100-in. axially and adjust the bearing towards or from the crankpin 1-1,000-in.

The rigidity, accuracy and delicacy of adjustment of this bearing are shown in the marine form of rod, Fig. 3. The bolts of the cap are drawn up tight and locked, thus holding the cap and the rod metal to metal, making it in effect as rigid as a solid end rod. The adjustment of the bearing is then made as frequently and as delicately as desired. For large marine engines, mechanism for working the adjustment could be carried to a point near the cross-head, so that the bearings of both the crankpin and the cross-head pin could be adjusted with the greatest facility, even while the engine is in motion. The more massive the rod the greater are the advantages of a rigidity that does not affect the ease and delicacy of adjustment.

The end pressure on B from the load is the resultant of the angle of inclination used, less the sum of the frictions on the two opposite surfaces of the wedge. Proportions can be used that will result in a practical equilibrium so far as the end motion of B is concerned.

Fig. 1 shows the application of the adjustment to an ordinary valve rod, in which the adjustable parts are placed in the rod in such a manner as to have the wear of the bearings affect the center to center length the least possible. The variation is here the difference in the wear of the two bearings instead of the sum of their variations, as is the case in the usual arrangement of the adjustments.

The very rigid form of this bearing, together with its delicate and accurate adjustment, makes it suitable for minute adjustments required in stamping presses.

It will be noticed that the adjustment of the bearing is a parallel motion, with large bearing areas, accurate surfaces and little or no tendency to get out of adjustment, either from long use or faulty manipulation. The delicacy of the adjustment, the mechanical accuracy of the bearing and the decrease in the cost of manufacture over the ordinary designs will be evident to shop men. The bushing is of the best form for securing accuracy of form combined with economic manufacture. The bushings can be renewed at a comparatively small expense, when the original length of the rod will be exactly restored.

*Abstract of a paper presented at the Milwaukee meeting (May, 1901) of the American Society of Mechanical Engineers.

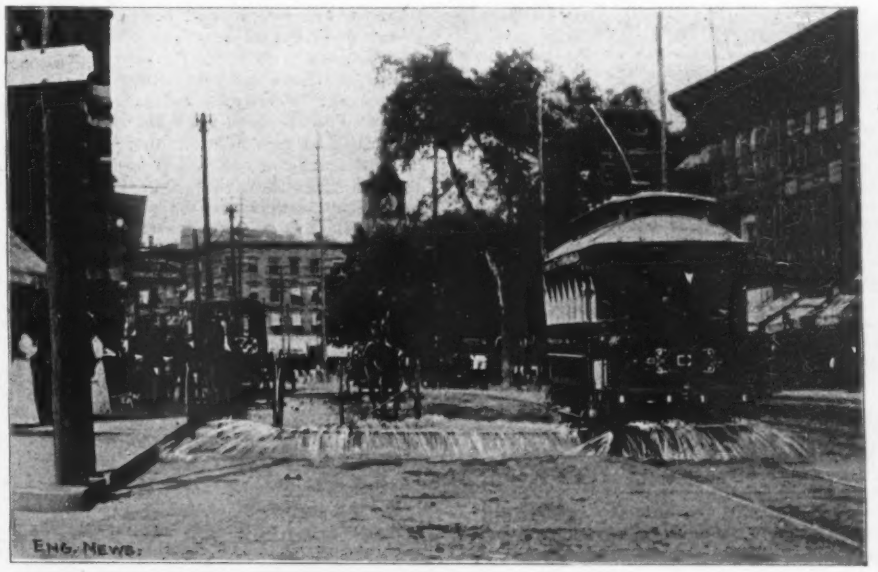
†45 Broadway, New York city.

A CURB-TO-CURB STREET SPRINKLER FOR USE ON ELECTRIC RAILWAYS.

Street sprinkling by means of street railway cars is common enough nowadays, but for the most part the service is limited to the space between the rails and a limited distance on each side.

A form of sprinkler covering half of the street at one car trip has been in use at Springfield, Mass., since 1895. It is also used at present in Holyoke, Lynn and Quincy, Mass., Hartford and New Haven, Conn., Louisville, Ky., Colorado Springs, Colo., and San Antonio, Tex.

As shown by the accompanying view, these cars do not greatly differ in appearance from the ordinary closed passenger car, except for the sprinkling attachments. The water is carried in a tank having a capacity of about 2,000 gallons, mounted on ordinary trucks and furnished with the usual motor equipment. A perforated swinging arm is attached to each side of the car, mounted to be set at right angles to the side of the car or to swing in against it. The connection between the sprinkling arm and the water tank is controlled by a valve, and both the arm and the valve are operated from the front platform of the car. To avoid complications with the traffic, only one arm is used at a time. By choosing the arm on the proper side of the car the sprinkling proceeds in the direction of traffic on the side of the street being watered. In case the arm strikes the hind wheels of a vehicle it swings back against the car. It is said that one car and two men (??) will do as much work in a given time as six sprinkling carts, twelve horses and six men.



A CURB-TO-CURB TROLLEY CAR SPRINKLER.

This system is controlled by the American Car Sprinkler Co., of Worcester, Mass. The company either leases its cars or operates them itself, as may be desired. We are indebted to the company for the foregoing information and for the photograph from which the view was prepared.

It would seem that a marked advantage of these sprinklers would be the frequent light sprinklings made possible on account of the relatively high speed at which they may be run.

The trouble with the ordinary wagon sprinkler is that it deluges the streets as it passes, which wastes the water and injures the surface of macadam paving. While visiting Chester, England, last summer, a member of the staff of this journal was told by the city engineer that he made the sprinkling cart drivers rapidly open and shut the delivery valve while sprinkling in order to reduce the amount of water applied. A sprinkling car can run twice as fast as an ordinary wagon sprinkler, and thus give the streets a light and even sprinkling.

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The folly of expecting Congress to administer the government of our new tropical possessions with the same ridiculous attempt at detail that it retains in handling domestic matters is becoming more and more clear as experience in our "colonial department" accumulates.

An excellent illustration of the manner in which Congressional interference operates in practice is furnished by the Foraker resolution, prohibiting the granting of franchises in Cuba. This resolution was enacted with the best intentions, and it has undoubtedly been of great benefit in checking the schemes of a host of irresponsible promoters and concessionaires. On the other hand, it has stood squarely in the way of legitimate and honest enterprise, designed to develop the country and give employment to labor.

A concrete example of this is furnished in a letter which we have recently received from Mr. E. J. Chibas, M. Am. Soc. C. E. As noted in this journal last year, Mr. Chibas has been engaged for some time in the development of an electric lighting system for Santiago, comprising 240 arc lamps for the streets and 6,000 incandescents for private lighting. A contract was made with the city authorities of Santiago to furnish the street lights at a certain sum per month for fifteen years, and its municipality was given the right to fix maximum rates for private lighting. The company was to have a right (but not an exclusive one) to carry its wires through the streets. It was supposed that since no exclusive privilege or franchise was to be received by the company, the Foraker resolution would not be transgressed.

The municipal authorities unanimously approved the scheme and the local U. S. engineer officer also approved it, stating that the rates offered compared favorably with those in similar cities in the United States, although the price of coal was twice as much. Nevertheless, the Havana authorities decided that the permit to carry wires through the streets was in conflict with the Foraker resolution and refused their approval. Mr. Chibas remarks in his letter to us:

> The decision may be in accordance with the letter of the Foraker resolution, but it hardly agrees with its spirit. That resolution was passed by Congress to check the horde of unscrupulous promoters and politicians which was sure to swarm in with the American occupation to try to secure concessions from the unstable and temporary government which would afterwards prove a burden to the people. For that reason the power to grant those concessions was rightly left to the people when they could approve them through their legitimate representatives elected by popular vote. That law was certainly a very wise one at the time it was enacted and none are more thankful than the Cubans for its timely announcement; but those conditions no longer exist.
>
> A year ago the municipal councils, the mayors and other city officials were elected by popular vote and they perform their regular functions independently of the military government. There is no reason why they should not be allowed to contract now for the necessary services to supply their local wants.

Of course, this is only one of many instances where the Foraker act has prevented the investment of capital and the employment of labor just at the time when such employment was most needed to enable the people to supply their daily wants and to recover from the disasters caused by the war. It is a concrete illustration of the way our permanent colonial possessions are pretty sure to suffer if Congress is to interfere in the detailed conduct of their government. Indeed, we may go further and say that if once the right sort of men are selected to administer local government, it will be better to give them a free hand. Neither Congress nor the executive authorities at Washington are likely to benefit matters by interference. Of course, we assume that the local authorities are honest and competent, working to secure good government and not to benefit their own pockets or those of political leaders. If this is not the case, all that either Congress or the department officers at Washington can do will not suffice to secure good government.

It must be remembered, too, that interference from Washington sometimes is brought about by other motives than the public welfare. At least one recent notable case comes to mind where it was political pressure from Washington that compelled the local authorities in Cuba to allow exorbitant claims which they were fully prepared to turn down.

The serious butting collision on a third-rail electric railway near Albany, N. Y., this week, calls attention anew to the dangers of operating electric railway lines without the safeguards which experience has shown to be essential to the safe movement of trains in steam railway service. If the press reports are true, this railway line was running cars at speeds of 40 miles an hour or more with no better system to keep cars spaced a safe distance apart than would be found on a horse-car road. That a collision occurred under such a system is nothing strange. On the contrary, collisions are to be expected about once in so often where such happy-go-lucky methods of operation prevail.

We know of no reason why electric railways should not be compelled to take as much precaution as steam railways to ensure the safety of their passengers. The difference in motive power makes no difference to the public. The list of seven deaths and thirteen seriously injured persons as a result of the collision on the Albany & Hudson R. R. ought to come like a warning to every electric railway manager who is still moving his cars by the old horse-car system—or lack of system. If his directors refuse the cost of a proper signaling system, the responsibility will at least be off his shoulders and on theirs; but recommendations of that sort from a managing officer are not likely to be turned down while the harrowing details of the Albany horror are fresh in mind.

SOME COMPARATIVE FIGURES RELATING TO SLOW SAND FILTRATION AT LAWRENCE, MASS., ALBANY, N. Y., AND MOUNT VERNON, N. Y.

Detailed figures relating to the operation of water purification plants have in the past been very scarce in this country. The lack of this important class of information will not be felt much longer, however, if only a few more works can be added to the list of those that keep such careful records of their operations as are to be found at Lawrence, Mass., Albany, and Mount Vernon, N. Y. But besides the mere keeping of the records, it is necessary that they should be carefully studied and analyzed in order that the lessons they contain may be readily available to the average practicing engineer, who has neither the time nor the necessary experience to do this work himself. This work of study and analysis has been done for the Lawrence records in an excellent manner by Messrs. Morris Knowles and Charles Gilman Hyde, in a paper which is to be read before the American Society of Civil Engineers on June 5,* and the results obtained at Albany were admirably set forth in the paper by Mr. Geo. I. Bailey, M. Am. Soc. C. E., published in our issue of April 9, 1900.

Through the courtesy of Mr. C. D. Turney, Manager of the New York Suburban Water Co., we are enabled to present in this issue a summary of the records of the Mount Vernon filters for the past six years, and some additional information relating to the management of that plant. We cannot lay claim to such an exhaustive study for Mount Vernon as has been made of the Albany and Lawrence records by the gentlemen named above, but the records at Mount Vernon appear to have been kept in fair detail and with care, although they are somewhat meager on the sanitary side. It will be interesting to compare the figures for the three cities, first giving some information relating to the filter plants in order that the data may be more readily understood.

The Mount Vernon plant was modeled closely after the one at Lawrence, and was put in operation less than a year later, or on Aug. 1, 1894.† These two filter plants are unique in that the surfaces of the filter beds are alternately ridged and depressed, their underdrains being placed in depressions in the earth, beneath the ridges of the sand. But while the depth of sand at Lawrence is 5 ft. at the ridges and 3 ft. in the depressions, the original depths at Mount Vernon were 2 to 1½ ft. (increased 6 ins. in 1900). The ridges are 30 ft. apart at Lawrence, against 15 ft. at Mount Vernon. At the latter place one grade of sand was used throughout, while at Lawrence a finer sand was employed at the points of minimum depth. At both places the depressions serve as channels for admitting the water on filling, but these channels at Lawrence were paved, while at Mount Vernon they are not.

The original scheme at each of these works was to operate the filters intermittently. It appears that this plan was carried out for only a short time at Mount Vernon, and that it has not been followed at Lawrence during the last few years. The Lawrence pumps, however, which deliver upon the filter beds, are shut down for awhile every night, the exact time varying with the consumption, the supply meanwhile being drawn from a 40,000,000-gallon storage reservoir. The Mount Vernon pumps are in constant operation in order to fulfil the terms of the contract with the city. The pumps deliver into a standpipe, which has a capacity of 292,000 gallons.

The water supply of Mount Vernon is drawn from impounding reservoirs on small streams. It flows by gravity to a reservoir of some 4,000,000 gallons capacity, located at the pumping station. The three filter beds occupy one corner of the original reservoir site. The filter beds have an available area of 47,892 sq. ft., or about 1.1 acre. They can be supplied either from the adjoining

*Published in the April "Proceedings."

†The three filter plants under discussion were described at length in the following issues of Engineering News: Lawrence, Aug. 3, 1893; Mount Vernon, Aug. 23, 1894; Albany, Feb. 10 and Oct. 20, 1898.

TABLE I.—Itemized Statement of Cost of Maintenance of The Lawrence Filter, for the Years 1895-1900.

	1895.	1896.	1897.	1898.	1899.	1900.
Scraping	$2,550	$1,350	$1,950	$1,930	$2,060	$2,130
And sanding		1,460	840	300	1,270	1,250
Conveying	1,320	1,180	2,200	1,660	1,470	1,410
Washing	1,000	2,120	1,950	1,000	1,450	1,510
Removal ice, &c.	2,780	2,350	2,330	3,480	2,300	2,330
General	450	490	850	710	500	720
Total	$8,100	$8,950	10,120	$9,680	$9,050	$9,350
Pr million galls	7.80	8.10	9.00	8.00	7.70	7.70
Total, less ice, &c.	$5,320	$6,600	$7,790	$6,200	$6,750	$7,020
Per million galls	5.10	6.00	6.90	5.10	5.80	5.80
Special repairs .	...	...	...	4,830	...	2,260
Total pumpage for year, mill. galls.	1,040	1,100	1,130	1,210	1,170	1,210

reservoir or from a cascade at one side. This cascade, besides affording a pleasing waterfall, was designed to be of possible service in the way of aeration whenever the water from the storage reservoirs would be benefited thereby. The total storage capacity, it may be added, is about 135,000,000 gallons, including the 4,000,000 at the filters. There is no storage for clear water, further than that afforded by the standpipe.

The Lawrence and Albany supplies are drawn from the Merrimac and the Hudson rivers, respectively, without previous storage. At Albany there is a 16,000,000-gallon sedimentation basin, a 600,000-gallon pure water basin, and the water after filtration is pumped to storage reservoirs. The Albany filters have an available filtering area of 5.6 acres, in eight covered beds; Lawrence, 2½ acres; Mount Vernon, as stated, 1.1 acre. The last two are not covered. The average daily amounts of water filtered at the three places during 1900 (1899-1900 for Albany) was about as follows, counting the full period and not the number of days the filters were in service: Albany, 11,200,000 gallons; Lawrence, 3,300,000; Mount Vernon, 1,860,000 gallons. This corresponds to average daily rates per acre of 2,000,000 gallons at Albany, 1,300,000 at Lawrence, and 1,700,000 gallons at Mount Vernon. The populations of the three cities by the census of 1900 was as follows: Albany, 94,151; Lawrence, 62,559; Mount Vernon, 20,346.

Coming now to details of operation, these happen to cover identical periods at the two older plants, Lawrence and Mount Vernon, the Lawrence figures for the first full year of operation (1894) not being available. The Lawrence figures for cost, alone, are given in the accompanying Table I., and the cost and various other items for Mount Vernon are presented in the first two tables in the article on that plant, elsewhere in this issue. In Table II., herewith, will be found an itemized total and unit cost statement for the last year's work at Lawrence and Mount Vernon, and also for the 339-day period at Albany.* The somewhat different methods of classifying the expenditures at the three plants makes it impossible to give an absolutely comparable statement, item by item, so we have thought it best to repeat the figures exactly as summarized at the several works. In our article on the Mount Vernon plant we have explained just what the various items include. These facts are obvious in the accompanying Albany statement. For Lawrence, the writers of the paper from which the figures are taken say that "scraping" includes wheeling the sand to a temporary dump; "conveying" (up to July, 1898) includes reloading the sand at the temporary dump and moving it to the permanent dump at the washer; "washing" includes (since July, 1898) the transportation of the sand from the temporary dumps to and into the washer, by means of a portable hopper, jet and pipe line. Removal of snow and ice, includes loading and moving in carts or sleds and dumping it into the river, except that since Jan. 18, 1896, an ice conveyor has been utilized to lift ice over the banks.

*In Mr. Bailey's article (Eng. News, Aug. 9, 1900) he computed his daily averages on the basis of the 319 days the plant was in actual operation.

TABLE II.—Cost of Slow Sand Water Filtration at Lawrence, Mass., and Mount Vernon, N. Y., in 1900, and at Albany, N. Y., from July 26, 1899, to June 30, 1900.

Lawrence, Mass. (1,210,000,000 filtered.)

Items.	Cost Total.	Cost Million gals.
Scraping	$2,130	$1.75
Scraping, &c*	1,250	1.02
Conveying	1,410	1.16
Washing	1,510	1.25
Remv'l ice,&c	2,330	1.92
General	720	.60
Total cost..	$9,350	$7.70

Albany, N. Y. (3,817,000,000 galls. filtered.)

Items.	Cost Total.	Cost Million gals.
Scraping	$949	$0.25
Wheeling out.	1,906	.50
Washing	1,858	.50
Refilling	1,490	.39
Clean'g basin.	210	.06

*Scraping and sanding.

Items.	Cost Total.	Cost Million gals.
Incidentals	761	.20
Water	209	.05
Total cost..	$7,392	$1.95

Mount Vernon, N. Y. (679,400,000 galls. filtered.)

Items.	Cost Total.	Cost Million gals.
Cleaning*	$893	$1.31
Overhaul.†	971	1.43
New sand	160	.23
Washing	512	.75
Removing ice.	145	.23
Miscellaneous.	68	.10
Total	$2,749	$4.05

* Cleaning and replacing; at times when two operations coincide.
†All sand removed, washed and replaced in sand beds.

It will be noticed that ice removal is a heavy item at Lawrence; that it was comparatively light at Mount Vernon in 1900, and generally so in other years. At Albany, the covered filters prevent the formation of ice.

The total cost of filtration at Lawrence is high, even when ice and snow removal is deducted. The authors of the paper point out that this is largely due to the heavy cost of scraping. It is evident that scraping and the conveying of the dirty and washed sand to and from the washer at these and other plants are items to the reduction of which the attention of engineers and waterworks managers must be turned in the near future. As Messrs. Knowles and Hyde suggest, some form of mechanical conveyor to replace wheelbarrows is desirable. Why might not the portable hopper, jet and pipe line now used at Lawrence on the small sand dumps at the side of the filters be adopted for use at each heap of sand on the filter bed? If this were feasible, and if the washed sand could be discharged from the washers onto the storage heap without manual labor, it appears that a great gain would be effected.

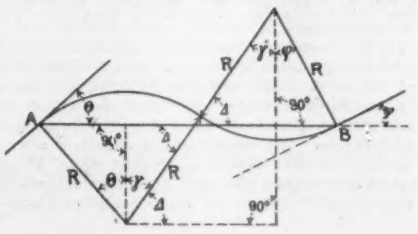
The cost of scraping the beds per 1,000,000 gallons of water filtered at Lawrence, from 1896 to 1900, is given in the paper as follows: $1.20; $1.70; $1.60; $1.80; $1.80. The cost of washing sand was 67 cts. per cu. yd. in 1895 and 1897; 62 cts. in 1898; 45 cts. in 1899; 50 cts. in 1900. The washer is of the ejector type. It was first used on June 17, 1895, and cost $540.

The itemized cost of filtration at the three places, for the latest available year, has been given already in Table II., herewith. The yearly variations at Lawrence, as shown by the accompanying Table I., have ranged from $7.70 to $9.00 per 1,000,000 gallons. The average for the six years has been $8.05. At Mount Vernon the range for the same period has been from $1.99 to $4.46, the latter including the complete renovation of the sand in 1900. The average cost at Mount Vernon for the six years has been $3.16 per 1,000,000 gallons. It should be said of the Lawrence figures (see Table II.) that special repairs were made in both 1898 and 1900, amounting to 50 and 25 per cent., respectively, of the cost of operation, and that these are not included in the unit costs. Attention should be called, also, to the heavy unit cost of snow and ice removal at Lawrence, which has been as high as $2.90 per 1,000,000 gallons. The unit cost of filtration at Albany, for the first 339 days of operation, was $1.95, as shown by Table II. This is about the same as the figures at Mount Vernon for the first three years, but at the latter place no sand was washed during the first two years of operation. Capital charges, it should be understood, are not included in any of the figures given. The excessive cost of filtration at Lawrence, as compared with both Mount Vernon and Albany, affords an excellent opportunity for discussion, which we trust will be improved at the meeting of the American Society of Civil Engineers, on June 5, when Messrs. Knowles and Hyde present their paper on the Lawrence filters. At that time, we presume, more recent figures may be made public for Albany. In fact, the paper may be expected to bring out a discussion on water filtration, both oral and written, which will add greatly to the valuable information on the subject which is now accumulating with such great rapidity.

LETTERS TO THE EDITOR.

A Problem in Railway Location; Reserve Curve Connecting Two Given Points.

Sir: I enclose herewith a direct solution of "A Problem in Railway Location," as stated in the News of April 11.



Given θ, φ and A B. Find γ and R.

$$2\,R \sin \Delta = R \cos \theta + R \cos \varphi$$

$$\therefore \sin \Delta = \tfrac{1}{2}(\cos \theta + \cos \varphi) = \cos \gamma$$

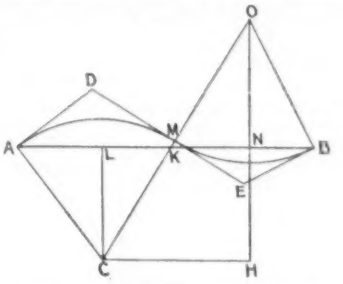
$$A\,B = R \sin \theta + 2\,R \cos \Delta + R \sin \varphi$$

$$\therefore R = \frac{A\,B}{\sin \theta + 2 \cos \Delta + \sin \varphi}.$$

Since writing the above I find that Nagle gives practically the same demonstration.

Yours truly, Malverd A. Howe,
Rose Polytechnic Institute,
Terre Haute, Ind., April 18, 1901.

Sir: I send you herewith a solution of "A Problem in Railway Location," published in Engineering News, April 11. This solution is taken from "Philbrick's Field Manual for Engineers," and is supposed to be the shortest and



simplest known. In the figure let B A D = A, A B E = B, A B = A, and R = the common radius.

Draw C L and O N H perpendicular and C H parallel to A B. Let H C O = B K O = C K A = K.

Then H O = C O sin K = 2 R sin K.

Also H O = C L + N O = R cos A + R cos B.

$$\text{Equating, we have } \sin K = \frac{\cos A + \cos B}{2}.$$

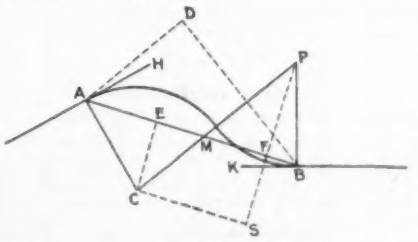
$$\text{Again, } A = A\,L + C\,H + N\,B = R \sin A + 2\,R \cos K + R \sin B. \quad \therefore R = \frac{A}{\sin A + \sin B + 2 \cos K}.$$

This solution avoids the use of radicals and requires barely a single division, except by the factor 2, and may be compared with Henck Problem 40.

P. H. Philbrick,
Chief Engineer, Kansas City, Watkins & Gulf Railway.
Lake Charles, La., April 15, 1901.

Sir: In your issue of April 11, under the heading, "A Problem in Railway Location," was given a solution of a problem which I think is handled in a somewhat simpler manner in the demonstration given below. This solution is an improvement by Prof. C. Frank Allen on one originally given by Prof. John B. Henck.

Problem: Given two points upon tangents not parallel, the length of line joining the two points, and the angles made by this line with each tangent. Required the common radius of a reversed curve to connect the two tangents at the given points.



Given length AB = l, angle HAB = A, angle KBA = B.

Draw PS and CE perpendicular and CS parallel to AB. Also BD perpendicular and AD parallel to CP.

$$PS = PF + EC$$

$$PC \sin PCS = PB \cos BPF + CA \sin CAM$$

$$2\,R \sin M = R \cos B + R \cos A$$

$$\text{Sin } M = \frac{\cos B + \cos A}{2}$$

$$ACM = C = 180° - AMC - CAM$$

$$= 180° - M - (90° - A) = 90° + A - M$$

$$BPM = P = 180° - BMP - PBM$$

$$= 180° - M - (90° - B) = 90° + B - M$$

$$BD = AB \sin DAB = AC \sin ACM + BP \sin MPB$$

$$l \sin M = R \sin C + R \sin P$$

$$R = \frac{l \sin M}{\sin C + \sin P}$$

A modification might be made after finding sin M, as follows:

$$AB = l = AE + EF + FB$$

$$= R \sin A + 2\,R \cos M + R \sin B$$

$$R = \frac{l}{\sin A + 2 \cos M + \sin B}.$$

Very respectfully, Charles B. Breed.
Mass. Institute of Technology,
Boston, Mass., April 26, 1901.

Sir: In your issue of April 11, 1901, I note a solution of a problem in railway location, viz: "to find the common radius of a reverse curve to unite the points A and B of the lines MA and BN (Fig 1)," given by Mr. Edwin E.

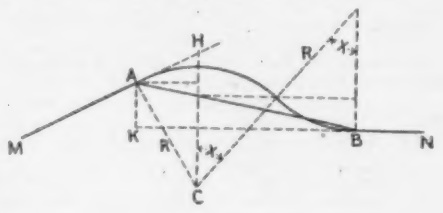


Fig. 1.

Woodman, of St. Paul, Minn. His formula:

$$R = \frac{AK}{2 \text{ vers } X - \text{vers } C} = \frac{BK}{2 \sin X + \sin C} \quad \text{(Fig. 1).}$$

Given AB, HAB = A, ABK = B, ACH = C = A − B, is difficult of application in that it involves the solution of a complex quadratic in X. A much simpler solution of this problem may be found in Nagle's "Field Manual for Engineers," page 106, under title "To locate a reversed curve between fixed points," and is:

$$R = \frac{k}{\sin I + \sin I' + 2 \sin x}. \text{ Also } R = \frac{k \cos x}{\sin a + \sin b} \quad \text{(Fig. 2).}$$

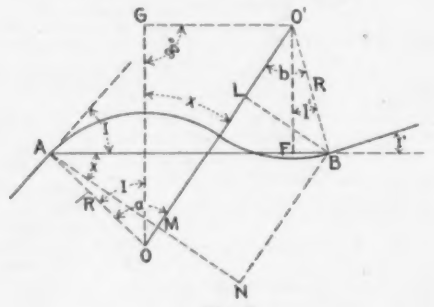


Fig. 2.

Given AB = k, AOG = I, BO'F = I'. O'OG = x, therefore $\cos x = \frac{\cos I + \cos I'}{2}$

Mr. Woodman's formula can be reduced to the one given by Mr. Nagle by substituting as follows:

Let AB = k, X = b = I' + x, and C = I − I'. Therefore

$$R = \frac{BK}{2 \sin X + \sin C} = \frac{k \cos I'}{2 \sin (I' + x) + \sin (I - I')}$$

$$= \frac{k}{\sin I + \sin I' + 2 \sin x}$$

It will be observed that this presentation of the formula can be adopted easily and is very simple.

Very truly, R. A. Thompson.

Engineer Railroad Commission of Texas,
Austin, Tex., April 21, 1901.

Notes and Queries.

Mr. Edwin C. Eckel writes:

My attention has been called to the fact that in my description of the process of the Catskill Cement Co., in Eng. News. of May 16, I erroneously stated that Smidth ball mills and Davidsen tube mills were used, whereas in reality both ball mills and tube mills are of Krupp type.

BLUE PRINTING BY THE ELECTRIC LIGHT.

We printed last week a description of the apparatus used by the General Electric Co. at its Schenectady works for making blue prints by electric light. A paper on the same topic was read at the Milwaukee meeting of the American Society of Mechanical Engineers this week by Mr. H. G. Reist, of the Schenectady works. We take from this paper the following additional particulars respecting the advantages of this system of making blue prints, and its cost compared with the ordinary system:

In summer it is possible with the sun blue-print frames to print all the time during office hours, and the percentage of time lost on account of cloudy and rainy weather is small. In winter it is not practical to print after about 4 p. m., and the amount of bad weather is a large part of the total time. In the belt in which I live it is cloudy as much as 60% of the time during the months of December and January. In cloudy weather the time required for printing is about 8 to 10 times as great as on a clear day, and on a rainy day it is not possible to print at all out of doors, except by a specially devised water-proof printing frame; but at such times the time required for changing prints is greatly increased, as the frame has to be wiped to keep from injuring the tracing.

From curves of the actinic value of sunlight for different times of the day and for different seasons, I have calculated that with a paper so rapid that it will print in 8 seconds in the sun at noon during July, the mean time required for making a print in January from 8 to 12 a. m. and from 1 to 4 p. m. is 2.33 minutes. Similarly, in July the mean time for the hours above (except that the time is extended to 5.30 p. m.) is 0.59 minutes; or the mean time for clear days during the year is 1.40 minutes.

Taking all the above into account, I find that the average number of prints made by one operator in winter per day is 26.4. In summer, the number of cloudy days is about 25%, and the average number of prints that may be made by one operator is 57.3, or more than twice as many as can be made in winter.

The cost of making prints by electric light is much smaller than one would expect, and the following figures indicate that it is cheaper to use artificial light than sunlight for this purpose. In printing by electric light, it is assumed that the cost of electricity is 12 cts. per K-W. hour, which is a fair commercial rate. The lamps are turned off when not in use. They are in use only 85 minutes per day for each operator. Each lamp requires 550 watts and the cost is 18.7 cts. per day. Labor is assumed at the rate of $1 per day.

	Sunlight.	Electric light.
No. prints per day, mean per year..	41.9	56.5
Cost of printing, per print.....	2.39 cts.	2.09 cts.

The time required for changing a print in sunlight is a little longer than when the artificial light is used, because the whole frame has generally to be moved, and the frame has to be adjusted to the proper angle to get the most effective sunlight. The time allowed for changing prints is 7 minutes when printing by electric light, and 8 minutes when printing by sun, while when printing during a rainy day as much as 20 minutes may be required.

It will then be found an advantage to use electric light printing as a supplement to the ordinary method, even if the latter method is not entirely superseded. Among other advantages may be mentioned the smaller space required for an installation for a given output than for sun printing; also, there will be less paper wasted, as the time for printing is much more uniform.

This method of making prints will especially appeal to manufacturers who are located where fogs occur, or where tall buildings may interfere with the normal sunlight.

BOOK REVIEWS.

BIOGRAPHICAL DIRECTORY OF THE RAILWAY OFFICIALS OF AMERICA.—Edited and compiled by T. Addison Busbey, Associate Editor "Railway Age." Chicago: The "Railway Age." Cloth; 6×9 ins.; pp. 613. $3.

The present edition of this very useful publication shows a considerable increase in size over the latest previous edition published in 1896. Altogether, it is stated, the names and careers of about 5,000 railway officials are given in the 613 double column pages of the present volume. Of course where so many persons are included, the only biographical matter possible is the briefest sort of a statement of the birth, education and previous and present positions held. These data are complete so far as can be judged by a hasty examination, and they are plainly and concisely given. Altogether the book is a creditable production and should be in the hands of every person who has use for the class of information it contains.

FIRST AID TO THE INJURED, AND AMBULANCE DRILL.—By H. Drinkwater, M. D. New York: The Macmillan Co. Cloth; 4×6 ins.; pp. 104; illustrated. 40 cts.

This book, both in contents and general handiness of size and weight, is peculiarly well suited to the use of engineers and others in the field and camp. After a brief but clear and simple description of the skeleton, muscles, nerves, circulation and respiration, the author tells just what should be done for temporary relief or safety after each of the various accidents to which all persons, regardless of location, are liable, such as hemorrhage, wounds, fractures, dislocations, sprains, burns, poisoning and drowning. The accompanying illustrations are quite as valuable as the text. It may be added that the volume is one of the series known as the Temple Cyclopedic Primers, which already contains a number of useful scientific books, with the promise of others to come.

TELEPHONE LINES AND THEIR PROPERTIES.—By William J. Hopkins, Professor of Physics in the Drexel Institute, Philadelphia, Pa. New and enlarged edition. New York: Longmans, Green & Co. Cloth; 5×7½ ins.; pp. 307; illustrated. $1.50.

As an introduction to the science and art of telephony this is a very excellent treatise. It lacks the completeness and detail found in Mr. Kempster B. Miller's "American Telephone Practice," but to the student and others wishing to obtain an elementary knowledge of the subject this is an advantage. The descriptions of apparatus are brief and concise and are illustrated by good cuts. The discussion of fundamental principles is not severely scientific, but perhaps sufficiently so for the purposes and scope of the work. Mathematical expressions are used very sparingly and are mostly placed in foot-notes. The latest developments, such as Pupin's method for long-distance telephony and wireless telephony are included. In regard to the latter the author expresses a hopefulness that, from the nature of the problem, appears to us to be unfounded. The titles of the chapters of the book are as follows: Design and Construction of City Lines; Underground and Long Distance Lines; Wire; Insulators; Exchange Switchboards; The Propagation of Energy; The Telephone Current; Measurements; Properties of City Lines; Interferences from Outside Sources; Properties of Metallic Circuits; Cables; "Composite" Working and Wireless Telephony.

GAS LIGHTING.—By Charles Hunt, Manager of the Birmingham Corporation Gas Works. Being Vol. III. of Groves and Thorp's Chemical Technology, or Chemistry in its Applications to Arts and Manufactures. Philadelphia: P. Blakiston's Son & Co. Cloth; 6×9 ins.; pp. 312; tables and 292 illustrations. $3.50 half morocco, $4.50.

In several respects this volume is a model of technical book writing. It is concise, well illustrated, presents a fair idea of the development of the art and gives considerable attention to the principal literature of the subject. To crown all, it is written by an experienced gas engineer who, if we mistake not, has grown up with the gas works of Birmingham, England, succeeding his father as manager of the works. While the book is written chiefly from the standpoint of British practice it takes cognizance of some of the most noteworthy features of American gas engineering.

The author arranges his chapters in accordance with the order of the various processes involved in the manufacture and distribution of gas, from the retorts and purifying apparatus to the burners. To most engineers not engaged in the production of gas, perhaps the chapter dealing with gasholder construction would prove most interesting.

Judged by American standards, we should say that the book is perhaps weakest in the section dealing with the recovery of by-products and in not including more information relating to specific works and details of works.

ELEVATION AND STADIA TABLES, for obtaining differences of altitude for all angles and distances; horizontal distances in stadia work, etc., with all necessary corrections. Together with hydraulic tables, giving velocities for various channels and slopes. By Arthur P. Davis, M. Am. Soc. C. E., Hydrographer, U. S. Geological Survey. New York: John Wiley & Sons. Cloth; 5 × 8 ½ ins.; pp. 43. $1.

These tables are compiled by Mr. Davis, as suggested by extensive practice in field work, and their use since 1893, in a less convenient form, has demonstrated their value. The first table is for obtaining differences of altitude, for any even minute up to 15°, and for any distance. Table II. shows the difference of elevation in feet for a distance of one mile, for even minutes up to 26°. Table III. is for correction for curvature and refraction up to 40 miles. Table IV., stadia distances and elevations, with even minutes up to 8°, and 5′ intervals from 8° to 20°. Table V., difference of elevation, corresponding to slant distance of 100. Table VI., correction for focal length. The hydraulic tables are based on Kutter's formula, with coefficient of roughness varying from 0.01 to 0.035. A table of convenient equivalents concludes the book. The tables are clearly printed on heavy paper.

TUNNELING.—By Charles Prelini, C. E. with additions by Charles S. Hill, C. E., Associate Editor, Engineering News. New York: D. Van Nostrand Co. Cloth: 6×9⅝ ins.; pp. 311; illustrated. $3.

It is truly said in the introductory chapter of this work that tunnels of considerable section owe their existence to railways and the broad engineering development of the last three-quarters of a century; for, while tunnels have been built since the days of Nimrud, it is the demands of modern civilization alone that have caused works of this character to assume great importance. The literature of modern tunneling is abundant enough in the proceedings of engineering societies and in the technical press, but in book form we have had in English heretofore only the magnificent, but bulky and costly work of Mr. Drinker, and the Simms-Clarke treatise on tunneling, which is out of date and confined quite closely to English methods. The advent of the present work will, therefore, be welcome to the engineer and engineering student, especially for bringing the subject up to date by its detailed and illustrated descriptions of recent and difficult tunnel works. The arrangement of the text briefly covers the subject from the methods of determining the center line, dimensions and form, to the completed tunnel. Tunneling through hard rock is illustrated by the practice of the engineers of the Mont Cenis, Simplon, St. Gothard and Busk tunnels, which is set forth at length. Under the head of soft-ground tunnels, the Belgian, German, English, Austrian and Italian methods are explained and illustrated by typical examples; and this is supplemented by a typical American method of soft-ground tunneling—the pilot system—introduced by Mr. John Anderson in the Hudson River tunnel and a Brooklyn sewer tunnel. Open-cut tunnel work is exemplified by the work done in Boston and that now in progress for the rapid transit tunnel of New York. The chapter on submarine tunnels introduces one of the most interesting and important sections of the work, containing as it does, detailed descriptions of the work done on the Chicago tunnels, the East River gas tunnel and the enormously difficult Milwaukee water-works tun-

nel. Under this same head we have the shield method of submarine tunneling, from its first use by Brunel to its latest application in the tunnels of London and Paris. Concluding chapters deal with accidents and repairs in tunnels, the relining of tunnels, ventilation and lighting during construction, the cost of tunnel excavation and the time required. In confining himself to a given space, the author has been somewhat handicapped by the extent of his subject and the many-sided development of the art of tunneling, and some topics in this connection have been very briefly touched upon, or, necessarily, omitted altogether. Among these is the equipment of a tunnel for hoisting and disposing of the waste material. On the whole, however, intended as it is primarily for the engineering student, the work is a very good general resume of modern methods of tunneling in all kinds of material.

THE STORY OF NINETEENTH CENTURY SCIENCE.—By Henry Smith Williams, M. D. Harper & Brother, New York. Cloth; 5⅛ x 8 ins.; pp. 475; illustrated; $2.50.

In this work Dr. Williams well performs the task assumed, of outlining the broad field of scientific discovery in the most eventful hundred years of the world's existence. In the arrangement of topics, in information given and in clearness of expression, the author leaves nothing to be desired; and he holds the reader fascinated, from the beginning to the end of his wonderful story. That we may better appreciate the full import of the scientific discoveries of the 19th century, he first sets forth in brief compass the sum of human knowledge at the end of the 18th century. While thoughtful men were then at work sowing the seeds that were soon to produce such a bounteous crop, in the light of present science, but little advance had been made over the preceding century. In 1800, the generality of men still credited the Mosaic deluge with all the irregularities of the earth's surface; to them fossils were the bones of giants of other days; light, heat and electricity were simply subtle forms of matter, and were classed among the "imponderables"; and the Aristotelian idea that earth, air, fire and water constituted the four primal elements still held its ground and formed the basis of all chemical philosophies.

It is typical of the promise of the 19th century to note that on the first day of this new era, Piazzi discovered Ceres, the first in a now long list of asteroids. The perfecting of the refracting telescope and the invention of the heliometer, by Fraunhofer early in the new century, first made it possible to measure stellar distances; and man began to realize that these distances were so enormous that in viewing the majority of the stars he was actually studying ancient history; for he did not see these stars as they are, but as they were; years, centuries or even millinea ago. Then the invention of the spectroscope enabled the astronomer to study the material substances of the stars; and by the aid of the camera he detected worlds hidden to the eye and telescope. Cuvier published his "Ossements Fossiles" in 1816, and founded the new science of paleontology; but it was not until 1851 that the old theories of deluge action and gigantic cataclysmic unheavals of the earth's surface gave way to the —at first derided—suggestions of the universal ice-age of Agassiz, now one of the accepted tenets of geology. One result of this deeper study of earth conditions and sequences was to broaden the life of our planet from a paltry 6,000 years to unmeasured millions.

In 1811, a "fire-ball," exploding in broad daylight over a meadow, was a miracle; we now know it to be a meteorite, and are familiar with its composition and its possible source. The beginning of the 19th century was signaled by the first scientific studies of the phenomena of light. In 1831, Faraday opened up the field of magneto-electricity. Perhaps the greatest discovery of the century was that of Joule, in 1840, when he demonstrated the precise and absolute equivalence between mechanical work and heat, a law which was to become the cornerstone of the greater law of the conservation of energy, as elaborated by Julius Robert Mayer, Tyndall and Helmholtz. It was only 20 years ago that James Clerk Maxwell gave to the world his speculations regarding the properties of ether; and it was very late in the last century when Professor Dewar and others proved that air, hydrogen and the most subtle of gases could be liquefied, and the absolute zero of temperature could be nearly reached, a temperature equivalent to 273° C. below the freezing point of water. The advance in the science of chemistry in the 19th century practically includes all that is known of that science to-day; and the same may be said of scientific medicine, biology, organic evolution, physiology and experimental psychology. The key to this remarkable growth in knowledge is found in the fact that the thinkers of the 19th century abandoned the old, delusive deductive methods of the preceding centuries, and for the first time began carefully to observe the world about them, and to study life as they found it in the animal kingdom of to-day, and in the remains of the animals of preceding ages. In this search the scientists of the 19th century were greatly aided by the vast number of scientific instruments invented as the demand for them arose; by the better facilities for penetrating the remote corners of the earth in search of new forms of life, and new conditions of the earth's surface, and by the rapid general advance in the sum of human knowledge, which demanded more light and found means of gratifying this demand.

But by no means the least interesting chapter in this most interesting book is one devoted to the unsolved scientific problems. No one can yet tell us of the source of heat in the sun; or the probable life of the sun as a heat-giving center. The so-called force of gravity is a mystery get unsolved; and chemistry presents many mysteries in the seemingly lawless action of different kinds of atoms in connection with other atoms. The habitability of other world than our own is yet unsettled, and the sum of all speculation on this head is a bald statement of possibilities. Among life problems, that interesting microcosm, the cell, still offers a multitude of intricacies for solution.

TESTS OF WASTE FOR PACKING CAR JOURNAL-BOXES.

By T. H. Symington.†

A large amount of money is expended annually on waste for packing journal boxes, the price of this waste ranging through the various grades of cotton and mixtures of wool and cotton from 3½ cts. for cheap cotton to 12 and 15 cts. for the best wool. The present method of grading waste is by the "feel," and its general appearance and freedom from dirt. This very crude method, and the desire to cheapen this item of expense, led the writer to some investigations which were interesting in their results as giving a more exact method of determining the value of various wastes for this purpose.

The qualities in the waste that are to be considered are as follows: (1) Its capacity for holding oil, or its absorbing qualities; (2) its elasticity when saturated with oil to the normal condition of packing for journal boxes; (3) its capacity for lifting oil by capillary attraction, or wick action; (4) the height to which this capillary attraction will raise the oil; (5) the length of fiber and the amount of twist in strands; (6) freedom from dirt and shoddy material which is liable to pulverize.

For this investigation, 29 samples of various qualities of wool waste and 17 samples of cotton waste were collected from manufacturers and railroad companies and tested in the following manner:

ABSORPTION TEST.—For this test, 1 lb. of each kind of waste was soaked in ordinary Galena car oil, at a temperature of about 65° F. for 30 hours, and allowed to freely drain for 10 hours, after which the samples were weighed, the increase in weight representing the absorption.

EXPANSION TEST.—In this test, each sample of waste, soaked and drained from the absorption test,, was placed in a tin bucket 8 ins. in diameter, and compressed by the use of a dasher and constant weight to about the tension of waste in a journal box, and allowed to stand for two hours. The height of the dasher from the bottom of the bucket was measured, and when the weight was removed, the amount of rise of the dasher represented the expansion of the waste.

CAPILLARY TESTS.—Fresh samples of dry waste of each kind were compressed in a similar bucket to that used in previous test, with the bottom of the bucket perforated with a number of holes. The waste was compressed by the use of the dasher and weight, and the bottom of the bucket placed just below the surface of a large tank of oil, and allowed to stand for 10 hours. The waste was then removed and weighed, and the increase in weight for each sample represented what might be termed the capillarity of the waste.

HEIGHT OF CAPILLARITY.—To determine the vertical height to which oil would rise in the various wastes, a small sample was placed in a glass tube about 2 ins. diameter with an open bottom. The waste was compressed in this tube uniformly, and the bottom of the tube allowed to come in contact with oil in a large tank. After standing for 10 hours it could readily be seen through the glass how high the oil had risen by capillarity in the waste.

SUMMARY OF TESTS.—From the accompanying table it will be noted that the absorption, capillarity, and height of capillarity of the cotton waste is considerably in excess of the wool. The expansion of the wool, however, is considerably higher than the cotton. This elasticity has been considered so essential that the expensive wool has been used almost universally instead of cotton in American railway practice.

Waste.	Absorption. Max.	Min.	Aver.	Expansion. Max.	Min.	Aver.
	%	%	%	%	%	%
Wool	573	237	325	39	8	22
Cotton.....	575	403	491	26	8	15

Waste.	Capillarity. Max.	Min.	Aver.	Height of capillarity. Max.	Min.	Aver.
	%	%	%	ins.	ins.	ins.
Wool	137	25	88	.2.50	.75	1.28
Cotton	215	37	131	.2.37	.59	1.72

The principal trouble with cheap waste seems to be that it goes to pieces in the boxes on account of being of very short fiber and shoddy material, resulting after a year's service in a pulpy, inert mass. The long fiber pure wool does not go to pieces, but retains its form and elasticity, and is therefore much superior to the shoddy material.

The capillarity of the waste seems also dependent upon the length of fiber, as the oil feeds the length of separate fibers, but will not pass from one fiber to another. One practical trouble with cotton waste has been that it would roll up in the box, leaving parts of the journal entirely bare.

The logical conclusion from these tests is, that if the cotton waste is held mechanically up to the journal, independent of its own elasticity, and is also held in the box so that it cannot roll up in knots, it would be as efficient packing as wool. As the cost of the cotton is so very much less than the wool, this would seem to open a field for large saving in the operation of cars. Several large roads have recently realized that with the ordinary boxes there is not a sufficient difference in the results obtained from wool over cotton to make it desirable from an economical standpoint to use wool at all.

The elasticity of the various wastes depends principally upon the tightness to which the strands are twisted, and on account of the variation in the elasticity of various kinds of cotton waste, it would be well in ordering such waste to specify that the expansion be not less than 20% in a test similar to the one outlined above.

*Abstract of paper read before the Western Railway Club, Chicago, May 21.

†Baltimore, Md., late Supt. of Motive Power, Atlantic Coast Line R. R.

NEW TYPE OF FREIGHT LOCOMOTIVES FOR THE CHICAGO, BURLINGTON & QUINCY R. R.

The standard freight engines on the Chicago, Burlington & Quincy R. R. have for some years been of the mogul type, with cylinders 19 x 24 ins. and 19 x 26 ins. The firebox was 40 x 108 ins., having a grate area of 30 sq. ft. and 1,689 to 2,047 sq. ft. of heating surface. The weight of the heaviest of these engines was about 143,000 lbs., with 121,500 lbs. on the drivers. It has been recognized for some time that engines with more grate area and heating surface would be necessary, and about a year ago a new type of engine was brought out, which has been named the Prairie type, the name applying simply to a certain arrangement of wheels. This is a modification of the mogul type, having a pair of trailing wheels behind the rear drivers, an arrangement which permits the use of a wide and deep firebox. The fuel used is bituminous coal and lignite, and this firebox is one of the special features of the new design. On account of its depth and moderately large grate area it is better suited for bituminous lump coal than the shallow Wootten firebox, so extensively used on engines burning small sizes of anthracite coal. Four engines of this type were built, these experimental engines having cylinders 19 x 24 ins., and carrying 190 lbs. boiler pressure, while the weight on the driving wheels was 110,000 lbs. The experience with these engines in regard to fuel economy and general efficiency has been so satisfactory that some 60 engines of the Prairie type, of larger dimensions that those first built, are now being built for the railway by the Baldwin Locomotive Works, of Philadelphia, Pa., and at the West Burlington (Ia.) shops of the railway company. Fig. 1 is a view of one of the Baldwin engines. The new type was designed in the office of the Superintendent of Motive Power of the C., B. & Q. R. R., and we are indebted to him for drawings and particulars of the engines now under construction.

The engines are not designed for hill climbing, or work on heavy grades, but mainly for service on a line with moderate grades, where it is intended to haul very heavy trains at pretty fair speeds. This requires an engine with very large boiler capacity to keep the cylinders supplied. The railway company has been making very large expenditures in grade reductions, with the result that the mechanical department finds that there is a very greatly increased demand upon the boiler. Undulating grades favor an engine with deficient boiler capacity, whereas long continuous grades or level stretches of track make it essential to provide engines with large boiler capacity to handle heavy trains.

All the driving springs are set directly over the boxes, and the springs are connected up by equalizers into two independent systems. One system includes the leading truck and the front driving axle; the other includes the two rear driving axles and the trailing axle. A lever resting on the box of the trailing axle has its rear end attached to coiled springs seated in the frame, while hangers on the front ends of these levers carry a transverse bar supporting the rear ends of the main equalizers behind the last pair of

driving wheels. This arrangement is an improvement upon that used in the first engines of the "Prairie" type. The principal novel feature in the equalizing is that the weight of the rear end of the engine is carried on outside bearings (on the trailing axle), and this has been found to have the effect of reducing the rolling of the engine. The rear equalizers are consequently outside of the line of the driving springs, and it will be seen that in connecting up the equalizing system between the trailing axle and the two rear driving axles, there is a transverse equalizer on which are supported the longitudinal bars or equalizers of the rear driving springs and the trailing axle. Hence, if the engine gives a lurch or roll, the weight of the boiler on the springs is transmitted partly across the engine and not wholly to the driving springs.

All the driving wheels have flanged tires. Those on the front and back axles are set 53⅜ ins. back to back, while the middle or main wheels are set 53⅛ ins. back to back of tires. The trailing axle is carried by extension frames, which are further apart than the main frames, and are outside the trailing wheels, both sets of frames being connected to a heavy cast-steel cross frame at the front end of the firebox and behind the rear driving axle. The trailing axle has outside bearings, which are not liable to be affected by the heat from the firebox, and has a lateral play of 1 in. each way from the center, which can be further increased to 2 ins. by planing off the flanges of the boxes. Its wheels are set 53⅜ ins. back to back of tires. The driving boxes are of cast iron.

The engines are simple, with cylinders 20 x 24 ins., and have 12-in. piston valves operated by the ordinary Stephenson link moton, the arrangement of which, however, is somewhat unusual. The link has a radius of 4 ft. 0¾ in. (standard with other engines), and carries a return lever or transmission bar which is suspended ahead of the link and operates the rock shaft, this shaft being placed between the link and the eccentrics. The arrangement is very similar to that of the ten-wheel passenger engines of the Southern Ry., illustrated in our issue of June 16, 1898; but in these latter engines the pivot of the return lever is between the rock shaft and the eccentrics. The piston valve is considered preferable to the ordinary flat slide valve for high pressure engines, from the fact that it is perfectly balanced. It has been used exclusively on all engines built for the C., B. & Q. R. R. during the past two years.

The boiler is of the straight top type, and has the dome just in front of the firebox. The extension front is rather long, but only extends 3 ft. from the center of the smokestack, making an easy inclination for the deflector plate. The tubes are of unusual length, 17 ft. 1 11-16 ins. over the tube sheets. The back end of the boiler is inclined so as to slightly reduce the weight without reducing the length of the grates. The firebox is of the Belpaire type, with the side legs sloping slightly outward from the crown, as shown in Fig. 2, so that it extends beyond the main or front frames and is carried on the back frames directly over the outside journals of the trailing wheels. There are two small oval firedoor openings, 12 x 15 ins., in the clear. The cab extends well back from the boiler head, so that there is freer communication between the engineman and fireman than on engines with Wootten or most other large fireboxes.

There are two main air reservoirs, 20 x 65 ins. under the running boards. No brakes are applied to the trailing wheels or the leading truck wheels.

The general dimensions are given below in our standerd form:

RUNNING GEAR:	
Driving wheels (6), diameter	5 ft. 4 ins.
Truck wheels (2), diameter	3 " 1¼ "
Trailing wheels (2), diameter	3 " 1¼ "
Tender wheels (8), diameter	3 " 0 "
Driving wheel centers, main, cast steel; front and back, cast iron.	
Truck wheels	Steel tired.
Tender wheels	Chilled.
Driving-wheel tires secured?	By shrinkage
Engine truck	Swing center.
Journals, driving axles	9 x 10 ins.
WHEELBASE: Driving	12 ft.
Total engine	28 "
Tender....16 ft. 10 ins.; Engine & tender	54 "
Engine truck-pin to c. of lead. driver	8 "
Wheels having blind tires	
WEIGHT IN WORKING ORDER:	
On driving wheels	130,0
On truck wheels	14,2
On trailing wheels	25,8
Engine, total	170,0
Tender, empty..40,000 lbs; loaded	106,0
Water in tank	6,0
Coal on tender	
Does counterbalance conform to M.M.Assoc. rules	

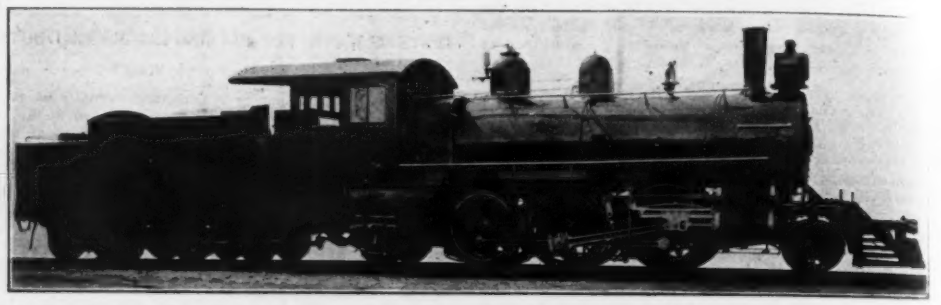
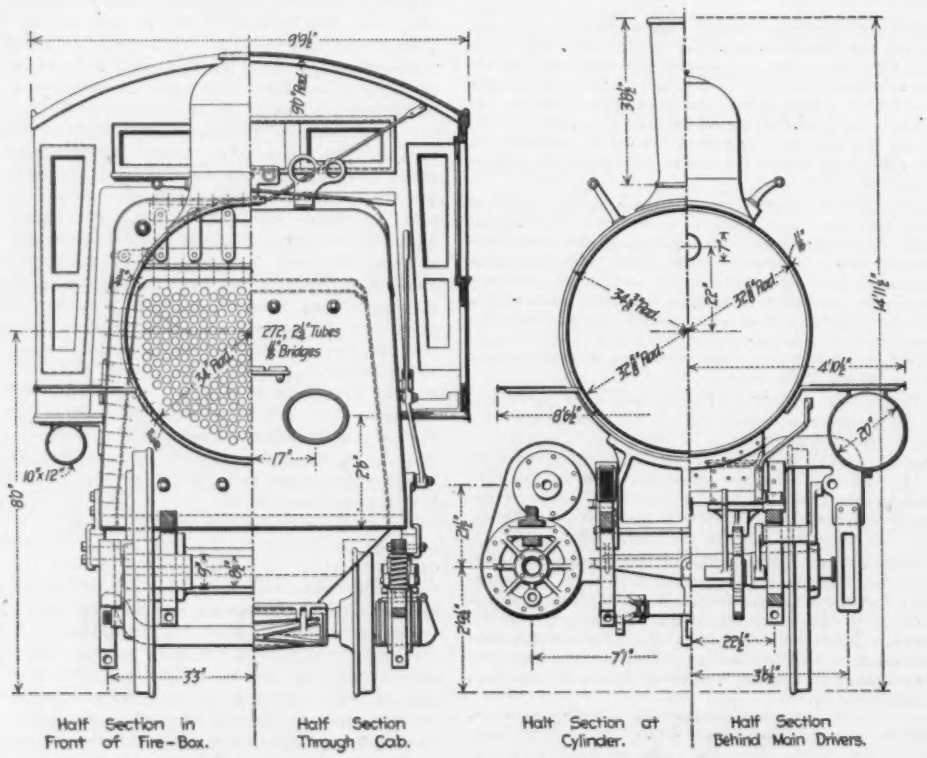


FIG. 1. NEW "PRAIRIE" TYPE OF FREIGHT LOCOMOTIVES; C., B. & Q. R. R.
F. A. Delano, Superintendent of Motive Power.
Baldwin Locomotive Works, Philadelphia, Pa., Builders.

CYLINDERS: Number	Two.
Diameter and stroke	20 x 24 ins.
Cubic contents of all cylinders	8.72 cu. ft.
Form of crosshead and guides	Laird.
Side rods	Solid ends.
VALVE GEAR: Type	Stephenson.
Ports: Steam..1⅛ x 18 ins.; Exhaust	3 x 18 ins.
Eccentrics, throw	5 "
Slide valves, style, Piston; Max. travel	6 "
Inside lap .....1 in.; outside lap. 1/16-in. clearance.	
BOILER: Type	Straight top.
Barrel, diam. inside smallest ring	5 ft. 3⅞ ins.
Dome, diameter	2 " 3½ "
Thickness, barrel plates	11/16-in.
Smokebox tube-plate	¾-in.
Horizontal seams	Sextuple riveted.
Circumferential seams	Double riveted
Joints.....Butt; Rivets, diameter	1⅛ ins.
Height from rail to center line	8 ft. 0 "
Length of smokebox, including extension	5 " 5 "
Does smokebox arrangement conform to M. M. Assoc. rules?	Not entirely.
Form of spark arresting device	Netting
Injectors	Two.
Working steam pressure	200 lbs.
FIREBOX: Type	Wide, over frames; Belpaire.
Length inside...7 ft. 0 ins.; width inside...6 ft. 0 ins.	
Depth at front..5 " 6¼ " ; depth at back..5 " 3¼ "	
Thickness, side plates ⅝-in.; back plate	⅝-in.
Crown plate.....⅜-in.; tube plate	½-in.
Crown stays	Iron.
Grate bars	Rocking and shaking.
Is fire-brick arch used?	Yes.
Stay bolts (drilled), diam. ⅞-in.; pitch	4 ins.
Water spaces, width at front	5 "
At back and sides	4 "
TUBES: Material.....Iron; Number	272
Thickness. No. 11, B. W. G.; pitch	2 5/16 ins.
Diameter, outside	2¼ "
Length over tube plates	17 ft. 1 11/16 "
Total area of tube openings	6.25 sq. ft.
HEATING SURFACE AND GRATE AREA:	
Heating surface, tubes (interior area)	2,732.7 "
" " firebox	155.8 "
" " fire-brick arch tubes	22.0 "
" " total	2,910.5 "
Grate area	42 "
Ratio of total heating surface to grate area	64 to 1
Ratio of int'r tube area to firebox heat'g surf.	14.6 to 1
Total heating surface to 1 cu. ft. cyl'd'r vol.	613 sq. ft.
Firebox heatg surf. to 1 cu. ft. of cyl'd'r vol.	39.5 "
Tube heating surf. to 1 cu. ft. cylinder vol.	57.4 "
Grate area to 1 cu. ft. of cylinder volume	9.6 "
MISCELLANEOUS:	
Exhaust nozzle, single; diameter	5⅜ ins.
Distance below center line of boiler	9¼ "
Smokestack, diameter at top, 18 ins.; base	14 "
Height above smokebox	4 ft.
Height of top above rail	14 " 11½ "
Capacity of tender tank	6,000 gallons.
Capacity of coal space	16,000 lbs.
Tractive force per lb., effect. press. on piston	139.4 "
Total tractive force with effect. press = 85% of boiler pressure	23,700 "
Total adhesive tractive power at ¼ of weight on drivers, (about)	30,000 "
Ratio of tractive force to weight on drivers	1 to 6



Half Section in Front of Fire-Box. Half Section Through Cab. Half Section at Cylinder. Half Section Behind Main Drivers.

FIG. 2. CROSS-SECTIONS OF "PRAIRIE" TYPE FREIGHT LOCOMOTIVE; C., B. & Q. R. R.

REQUIREMENTS OF ELECTRICITY IN MANUFACTURING WORKS.*

By Wm. S. Aldrich, M. Am. Soc. M. E.†

This paper briefly considers some essential features of electric power transmission in manufacturing work. The ever-widening applications of electricity in manufacturing work show that it has fully proven its claim to a consideration. It is thoroughly reliable. It has come to stay. It fills the exacting requirements in this new field more

*Abstract of a paper presented at the Milwaukee meeting (May, 1901) of the American Society of Mechanical Engineers.

†Professor of Electrical Engineering, University of Illinois, Champaign, Ill.

economically and satisfactorily than any other system of power transmission. In the common forward movement of industry electricity is still in the van. It stands ready for any emergency within its province and so far has been equal to each new demand made upon it.

Aside, however, from all purely technical considerations of the application of electricity to manufacturing stands pre-eminently the question: does it pay? Many manufacturers have conclusively shown that the economies of production have been enhanced by their adoption of electricity, that its inherent advantages in this relation far outweigh all previously debatable questions of economy and efficiency of the electric drive compared with belting transmission and that even if there were no saving at the coal pile it would still not pay to return to the old method and lose orders.

GENERAL CONSIDERATIONS.

ELECTRIC TRANSMISSION IN MANUFACTURING WORK IS A MEANS TO AN END.—Centralized power generated for light and manufacturing purposes; subdivision of the transmission system and the motive power equipment; execution of all classes of work, irrespective of its location; maximum efficiency of workmen, machines and labor involved; intensified production at best speeds and at the power limit of machines with improved quality, maximum output and reduced cost.

SANITARY CONSIDERATIONS.—It is healthful, clean, and free from dirt, dust and dripping oil; it affords accommodations and facilities for proper lighting and ventilation; it removes dangers from overhead machinery shafting and belts; it reduces the sick list to a minimum; it insures quietness from absence of much unnecessary noise with older systems, and develops cheerfulness in workmen.

DISCIPLINARY VALUE.—It improves the morale and the personnel of workmen; it conduces to shop order and discipline, with the most economic use of the workman's time, quick handling of material and maximum efficiency of labor.

FLEXIBILITY OF THE SYSTEM.—Accessibility of all parts, adaptability to various uses, and portability of tools are inherent advantages.

RELIABILITY OF SERVICE.—It is free from any general breakdown, localizing casualties and stopping least machinery for repairs; no accident can affect the whole plant in any case of a modern electrical installation properly designed, equipped, and operated; it is more to be depended upon than any other system.

ECONOMICS OF ELECTRICITY IN MANUFACTURING.

ELECTRIC POWER GENERATION.—This system admits of centralized or concentrated power generation which is required for maximum economy. Distributed power generation in small and scattered units is very wasteful.

The electric power plant may be located to best advantage for fuel and water supplies, conveying and transportation facilities. It may be isolated from other structures, so reducing fire risks and insurance rates, especially where the boiler house is in a separate building.

The electric generating sets may be subdivided into similar and independent units. These may be operated at all times under the most economic condition of normal loads. This permits manufacturing work in any branch or section of the establishment as economically under part load as under full load, on overtime and night shifts as during the day's work.

Electric light may be supplied from the power mains or from separate generators, as conditions require. In not a few cases of the introduction of electric driving the additional saving has been more than enough to pay for all of the lighting service.

The cost of generating electric power can only be a deciding factor when the total cost of power required is large compared to the running expense. The saving in fuel depends upon the cost of fuel, the average load, the amount of shafting and belting displaced.

ELECTRIC POWER TRANSMISSION.—The distances are short in factory service, the electric distribution being within one building or a group of buildings. The so-called line losses are therefore usually negligible in well-designed installations. Low voltages are employed in factory transmission. From 110 to 550 volts are the accepted limits at the present time in this country, either for direct or alternating-current working at constant potential or pressure. The economics of the various systems can be only satisfactorily discussed with reference to any given project or installation.

The following are recognized methods of distribution, for electric light or power, or both, in manufacturing work: Two-wire and three-wire systems, for direct or alternating currents; multi-circuit system for direct-current multi-voltage service; single-phase, two-wire alternating current; two-phase, three or four-wire alternating current; three-phase, three or four-wire alternating current; composite system, direct current and single-phase or two-phase alternating current on the same wires.

THE FIRST COST OF ELECTRICAL INSTALLATION.—This will usually be higher for an electrical than for a mechanical transmission. The interest on first cost will rarely be a determining factor. It will be more than offset by the manufacturing economics elsewhere effected and by the reduced cost of shop buildings incident to the use of the electric drive.

MAINTENANCE OF ELECTRIC SYSTEM.—The cost of maintenance is a minimum. The depreciation is less than in any other system. The saving effected is much more than sufficient to pay for all of the incidental repairs and renewals to the electrical machinery or the wiring system. Attendance and supervision are largely centralized and reduced to a minimum compatible with efficient service, owing to the reliability of the system.

Electric generators and motors are the simplest types of motive-power machinery that can be used in the development of power transmission for manufacturing work. They have the fewest parts requiring any renewals. They require practically no repairs. Electric machines will either work or not work. They soon make their wants known. They cannot be maintained in wasteful operation, as is the case with every other kind of motive-power machinery. Standardization of this class of electrical machinery has facilitated repairs. They are quickly and easily made, at minimum cost and with least interference with the routine work of the establishment. Small electric motors in general require more frequent attention and renewals than larger machines. Belt tightening or lacing in the old system stops work on that section, and stops all work if it chances to be the main driving belt. Any similar casualty in the electric system is remedied at once by throwing into service another line, or a jumper, or a relay bus-bar.

INFLUENCE OF ELECTRIC TRANSMISSION UPON FACTORY BUILDINGS.

The design, plan, and arrangement of manufacturing establishments are not now dictated or controlled by the new electric transmission, as always has been the case with the old mechanical system. Factory and mill construction is undergoing radical changes incident to the electric transmission of power. There is now a superior adaptation of the building to manufacturing work and sanitary requirements, with higher ceilings for light, ventilation, and overhead transportation. The cost of buildings is reduced to a minimum. The electric drive does not require the heavy construction of walls, overhead work, and roof trusses demanded by shafting transmission.

The site for buildings may be chosen independent of power considerations and located on most suitable ground. There is no necessity for buildings being placed around or adjacent to the power house, as required for mechanical connections to engines or turbines. Grouped shops may be arranged in best manner to facilitate economic production and the handling, conveying and transportation of material and work. Detached buildings, a tendency of certain lines of modern manufacturing development, are feasible and the work therein facilitated by electric transmission. The isolation of various shops, departments and workrooms for manufacturing or insurance reasons may be carried to any extent with the electric system without impairing its efficiency or economy. The output per square foot of floor space is a maximum with electric transmission.

INFLUENCE OF ELECTRIC TRANSMISSION UPON WORKSHOP EXPANSION.

Future areas of work may be planned and arranged for with the utmost freedom and entirely irrespective of power considerations. They can be located as desired, on separate floors, in various departments or in detached buildings. Original provision for prospective development is not necessary in the electric system, but is required by shafting transmission. There is no expense for contemplated additions till they are actually installed as required.

Permanent additions to the electric generating plant and the distributing system are made with a gradual and pro rata outlay of capital, instead of in disproportionate blocks of new equipment, as required by mechanical transmission.

Extensions of electric transmission and new centers of power distribution may be established at any time and of reasonable capacity, anywhere and at any distance, at minimum cost for labor and material. There is no crowding, overloading, or interference with existing conditions, or with the daily progress of routine work. Temporary extensions, to meet sudden demands for power at any point, are quickly made by running to the desired location electric wires or cables. These are easily removed when no longer required and as readily used elsewhere for similar purposes. The shifts are made with the least expense of time and labor in handling, and with no accompanying waste of material to suit different conditions.

Auxiliary power is always at hand for emergencies and to almost any reasonable extent, on account of the reserve nature of the electric supply.

INFLUENCE OF ELECTRIC DRIVE UPON ARRANGEMENT OF MACHINERY.

The floor space required per machine or tool is reduced to a minimum. The alinement of overhead shafting is no longer necessary. Clear overhead room is provided for handling all classes of heavy work. The crowding and complications arising from overhead shafts and belts are avoided. Location of machines and tools may be made to suit the requirements of the work and the available floor space. The product may then be finished with least time and labor, with least handling and transportation, and in the most efficient and economic manner. All the conditions of work and of labor may be arranged to handle tools and material to the best advantage with freedom of workman's movements and facility in executing manufacturing operations.

CHANGING FROM THE OLD TO THE NEW SYSTEM OF DRIVING.

When alterations or additions in power transmission are required, it is the invariable practice in many modern shops to extend in the line of electric driving. This is notably the rule where electric supply is already at hand for either lighting or power service. In the rehabilitation of an old establishment some of the shafting transmission may usually be combined with the electric drive, as in the so-called group system. Much can be done to improve the power transmission if existing lines of shafting are divided into the most economic sectional lengths, determined by the speed, character of load, and kind of work. Electric motors will prove valuable adjuncts if installed to drive these sections independently. The electric drive is an economic and flexible auxiliary, supplementing the earlier and rigid mechanical power transmission. Such partial introduction of the new system, especially if an electric lighting plant is already in service, will early develop its advantages. It will defray the cost of installation and maintenance by greater economic production.

Scrapping the old to make room for the new involves the same economic questions in the case of power transmission as in that of manufacturing machinery. Productive machinery should not in general be scrapped while there is retained the old system of belt driving, with its inherent power and speed limitations. The increased output of the old machine, electrically driven, will frequently equal that of a new machine, belt driven, and turning out the same kind of product.

APPLICATION OF THE ELECTRIC DRIVE.

INDIVIDUAL DRIVING WITHOUT INTERMEDIATE GEARING.—The armature of the motor is mounted on the main spindle of the machine. The power is most directly applied, with ideal adaptation of tool to work. It requires more or less special adaptation of motor to machine, with rarely any marked changes in the structural design of the latter.

INDIVIDUAL DRIVING WITH INTERMEDIATE GEARING.—The motor is conveniently mounted on the frame of the machine and drives it through the intervention of the ordinary gearing. It requires no special adaptation of motor to machine. Any suitable motor may be used on any machine.

ADVANTAGES OF THE INDIVIDUAL DRIVE.—The workman has the most perfect control of all factors entering into the economics of production. There is maximum economy in the application of power. The speed control and the ouput are independent of any other machine. They are no longer limited by the speed of the line shafting. Machines and tools may now be worked to the limits of their respective capacities. The productive efficiency of the machine is increased. It may be operated at all times up to the power limit, reducing time and cost of labor for any given product. The choice of the individual drive depends upon the power required, the size of the machine, the time it is in service and the value of the product.

The individual motor drive is usually adopted where the machine is in use only part of the time, and in sizes as small as two or three horse-power, and requiring wide variations in speed and power for maximum output quite independent of the first cost. For large machines this method reduces the power losses to a minimum. It is particularly advantageous for shears, punches, and a class of repair shop tools requiring power only at intervals. The constructive details and design of direct-driven machines are not usually altered to any extent; secondary speed changes are obtained by the usual change-gear and mechanism; in special cases of large tools, a range of speeds is sometimes best provided by a special variable-speed motor.

GROUP DRIVING.—A few large electric motors are employed independently driving sections of shafting of most economical length. This method is thus adapted for driving a number of small machines, with no particular requirements in speed or in power; or for most economical manufacturing along special lines; or for driving any section on overtime or night shifts; or for independent driving of separate floors, departments, or detached buildings.

The maximum economy with the group system can only be secured when all of the machines so driven are in constant use, at best speeds for maximum output. This dictates grouping machines as far as practicable of the same size, style, functions, speed and power requirements, having due regard to the work to be executed. Sectionalizing the power transmission by substituting electric motors for either the main or section belts secures partial advantages of the new system side by side with the old, and is frequently resorted to in old establishments adopting new methods.

INDIVIDUAL AND GROUP DRIVING.—The most general requirements of factory transmission can all be met by an intelligent combination of these two methods of

electric driving. The first cost of installing the individual drive will generally be from 2 to 5% higher than for the best group system, when all other considerations are the same. The individual drive is more economical in the use of power than the group system, especially if in the latter only a limited number of grouped machines are in use at any one time, at average loads.

PORTABLE TOOLS AND APPLIANCES.—The extreme flexibility of the electric system invites the widest use of portable tools and appliances. A flexible heavily-armored cable gives any desirable radius of action, with no expense to maintain as a part of the transmission system, with no danger or difficulty in handling, and requiring least time and labor for any immediate shifting of tool or work. Least used tools need not occupy floor space when not in operation. Most favorable economic relations may, therefore, be secured in many lines of manufacturing work, especially of the heavier grades. Almost all required tools may be taken to and operated at the work in hand. Time is saved in not having to shift and adjust the work to the machine or tool. Several operations may be carried on at one time by bringing different tools to the work, each independently driven and operated.

ELECTRIC TRANSPORTATION AND CONVEYING.—Electric hauling by surface or overhead systems of distribution, electric conveying and telpher systems, electric cranes, hoists, lifts, and elevators, are all well-developed fields, and present no unusual nor insurmountable difficulties when installed as a part of the regular electric system of a manufacturing establishment. Tools are taken to the work, or machines and tools are quickly served with material and work, reducing the cost of all handling to the lowest terms in a field of non-productive labor that has formerly been very expensive.

ELECTRIC-DRIVEN AUXILIARIES.—With an established electric supply service for all manufacturing work it is an economic step to drive by electricity all auxiliaries, as pumps, fans, blowers, air compressors, etc.

SELECTION OF EQUIPMENT.

FACTORS DETERMINING CHOICE OF THE ELECTRIC SYSTEM.—Each manufacturing industry has its own inherent requirements. No general rules can be given, but every case must of necessity be studied and developed by itself with a thorough preliminary survey of all conditions and requirements. One successful system cannot furnish precedent for another.

In general, the following lines of inquiry should be freely investigated before choosing any system for power transmission in manufacturing work: the size of the establishment; the area to be served; the arrangement and grouping of shops, departments or buildings; the arrangement, types and sizes of machines or tools to be driven; the variety of speeds required; the character of the loads involved; the kind of work to be executed; the economics of fuel and water supplies.

The above items should have been predetermined from the standpoint of most economic production. They should in no wise be influenced by questions of power transmission. How to drive the machinery in a new and modern manufacturing plant should be a second and not a first consideration. It should be determined by, rather than itself determine, the conditions for economic production.

INTERCHANGEABILITY THROUGHOUT THE ELECTRIC SYSTEM.—It should be possible to drive similar apparatus and motors from any point of attachment to the wiring system. Greater flexibility is thereby secured, added facilities provided for use of portable tools, and readiest extension made of plant and distributing system at any time. Preferably have one, and only one, electric system if it can be secured by intelligent consideration of all present and the most probable future requirements. This does not necessarily imply that it is best to have one single circuit for all kinds of service required in a manufacturing establishment, as light and power; but it should not be required to use different circuits for the same service, as portable tools.

UNIFORMITY OF ELECTRICAL EQUIPMENT.—Generating sets and motor equipments should be standardized as far as possible in the case of any given establishment. These machines, as well as all their parts, should be readily obtained in duplicate at any time. This is particularly important in making additions and extensions in the group system, where it may be required to change from a smaller to a larger motor at any time to accommodate more machines on a given section. It cannot be advantageous to experiment with different styles and types. Electric machinery to-day is so far standardized, and its performance predetermined, that there can be no excuse for not selecting that style and type best adapted to any given factory.

POWER REQUIRED AS A BASIS FOR SIZE OF ELECTRIC MOTOR.—The load diagram for any machine will furnish the best data for determining the proper size of motor. It may be readily obtained under the working conditions of the machine by using a test motor.

In almost all metal-working industries the power required is subject to extreme fluctuations, and may be very heavy, at times, while the bulk of it will be quite light. It is not necessary to instal an electric motor to carry, for any length of time, such sudden and heavy loads as will be shown by the peaks of the load diagrams for the several machines, or the sudden initial throw of the ammeter needle.

The limit of overload is fixed by the allowable rise of temperature, and can readily be predetermined for any given electric motor. In general, the surface temperature of the motor field coils, as measured by a thermometer, should not exceed from 35° to 40° C., with a maximum limit of 50° C., after an overload run of from 6 to 18 hours, as may be specified by the builders.

Starting load currents are of course high, and may be from two to three times the normal current, as in the case of overloads, for brief periods. Individual drives require proportionately larger motors to enable them to carry alone the heavy overloads. Group drives require only normal load motors, as it will rarely ever occur that the several grouped machines are all carrying overloads at the same instant. Motors for this service may often be much smaller than would be dictated by the combined load diagram of the machines forming the given group or section. In no case will they require to approach the maximum, or the sum of the maximum, loads of the various machines. Group system load curves will be smoothed out considerably. In all electric motor installations there should be ample power provided, rather than a narrow margin only to work upon. Increasing loads are almost sure to arise in time. A motor of ample size gives that reserve power so characteristic of the electric system, if properly installed.

CHARACTER OF LOADS IN MANUFACTURING WORK.—Load curves and diagrams of individual machines, groups, sections, and the entire plant, only can be relied upon in estimating the character of loads being carried or likely to be carried under similar conditions. The load factor, the ratio of the maximum to the average load, for any given time on any part of the system, should be as high as possible for best working efficiency and economy. It may be largely influenced by the way the operator handles his motor. Whatever the kind of load, uniform or variable, light or heavy, continuous or intermittent, suddenly fluctuating or periodically variable, it must be carefully investigated before installing electric motive power. In certain instances flywheels may be useful and for the same mechanical reasons as elsewhere employed in machinery.

SPEEDS OF MANUFACTURING MACHINERY.—The speeds should be predetermined by the conditions for most economic maximum output, and so fix the range required for the electric motors. In no instance should the reverse be the case. In many cases of individual drives it may be best to secure the speed reductions mechanically, as by the ordinary change-gear. It is not necessary nor advisable in all cases to secure the same by mounting the motor armature directly on the spindle of the machine. Provide motors with speeds consistent with the range of change-gear, and gear down rather than up.

ELECTRIC GENERATORS REQUIRED IN MANUFACTURING PLANTS.—The style and type should be largely determined by the kind of service to be supplied, the size by the normal and overload conditions as shown by the plant load diagrams, with due considerations given to special conditions and variable loads.

The actual normal capacity of the generator will be chiefly determined by the length of time the various motors are in use, rather than by their normal or aggregate capacity. It may happen, owing to the intermittent use of machines and motors, that the generating plant may be reduced to 50%, or even to 20% of the aggregate normal capacity of the motors out in the establishment. An increase of the electrical system can only be intelligently made from a careful study of the load curves of the existing installation, and using it as a basis for comparison with the probable load curve under the proposed conditions. There should be judicious subdivision of the generating plant into units, preferably of the same size and style, that they may be readily interchanged and duplicated at any time, with one or two relay units for emergencies and extra rush seasons of work. All generating units used in manufacturing installations will necessarily be of such size as to warrant their being driven by direct connection to engines or turbines. If generators required are too small to warrant direct connection, the establishment is too small to warrant an introduction of the electric drive

THE ELECTRIC WIRING AND DISTRIBUTING SYSTEM.—All wiring should be done in accordance with the "National Electric Code," being the rules and requirements of the National Board of Fire Underwriters. Separate service circuits, from the same or separate bus-bars, may be provided to advantage, for lighting and various power uses. Sub-stations, or sub-station switchboards, should be provided for separate shops, floors, departments, or buildings, making it unnecessary to run a separate set of wires back to main switchboard for each service.

INDIRECT ELECTRIC DISTRIBUTION.—Indirect distribution, through the use of accumulators, converters, or transformers may be found expedient under certain conditions. For the three-wire systems, some type of accumulator or motor-generator balancing set is almost essential for efficient regulation. The accumulator may render as invaluable service in certain kinds of factory installations, as in iron and steel mills, as it is now rendering traction work, where the character of the variations of the former is somewhat analogous to the latter. The loss in the battery is very small and entirely negligable compared to the advantages to be derived from its use in manufacturing plants of the kind mentioned.

LOSSES IN FACTORY TRANSMISSION.

The inherent losses common to all systems of factory transmission are due to the intermittent and irregular use of the machines driven. These are reduced to a minimum with the electric drive. There is no consumption of power when the motor and machine are not in operation. There are no power losses when the motor is not in use, no so-called dead load losses, due to mechanical friction of the shafting system, no transmission losses in the line when the electric current is not required.

Electric generators and motors, when in operation at uniform speeds, have, generally speaking, but two kinds of losses: the first is a constant quantity depending upon the size and type of machine; the second is a variable loss proportional to the square of the current in the armature circuit. The electric line and other wiring has a loss proportional to the square of the current carried. The cost of waste power in the mechanical system becomes excessive at light and frictional loads. It is saved in the electric system, in which the constant losses are minimized and the variable losses are throughout proportional to the amount of work being done.

EFFICIENCY OF ELECTRIC TRANSMISSION.

The efficiency of the electric system under normal conditions shows high maintained values, from about 25 to 35% underload to the same amount of overload, for the individual generators and motors, as well as for the aggregate efficiency of the installation. In mechanical transmission there is a constant falling off in efficiency at various underloads in every part of the system, owing to the inherent losses due to mechanical friction, which losses are constant at all loads and constant speeds. It is not a question so much of the individual efficiencies, in either case, as of the aggregate or combined efficiency, from engine or turbine shaft to machine or tool. The performance should be considered and compared at proportional parts of the full load as well as at normal loads. The mechanical efficiency of all manufacturing machines is almost invariably low. It is possible materially to effect it by efficient motors properly selected, installed, and operated. The all-day efficiency may be made higher with the electric drive than with any other system, as the amount of time is minimized during which machines and tools are necessarily idle.

OPERATION AND TESTING OF FACTORY INSTALLATIONS.

THE GENERATING PLANT.—As far as practicable, each unit should be operated at its normal capacity—additional units to be switched in as may be required by the manufacturing conditions.

THE MOTORS.—It is rarely the case that any machine or tool is started from rest with full load upon it. Motors may be started best under the usual friction, or light loads on the machines, as in the belt systems. When the machine is brought up to proper speed, work may be thrown on to it. In this respect the practical operation of an individual electric drive follows closely that of the belt system.

It is always possible to tell exactly what is going on in an electric drive, both in kind and amount of useful work, as well as in matter of wastes and losses. Power measurements are made at any point by ammeter and voltmeter, or by a wattmeter alone. A special test motor of known performance lends itself admirably to comparative tests of the performance of machines and tools under various conditions. Workmen may know at any moment whether they are driving tools or machine to best advantage for maximum output at best speeds.

The definite power required for definite work may be determined and charged to each machine, tool, or piece of work, and so make up the shop cost of production more exactly than by any other system. The power lost in friction of individual machines when running empty may be obtained with equal facility and compared with that required in doing useful work. It will be found that the latter increases almost directly as the resistance being overcome by the machine in its operation under working conditions. The power required by the work is a small per cent. of the total power delivered to the machine.

THE ACCURATE MEASUREMENT OF ANGLES WITH THE ENGINEER'S TRANSIT.

By P. D. Cunningham.*

During the years 1893-96 it was necessary for the writer to accurately determine angular values in triangulation schemes to control topographical work, when ordinary engineer's transits, with horizontal limbs of 5½ ins. to 6½ ins. diameter, graduation to 20′ increasing from left to right and ver-

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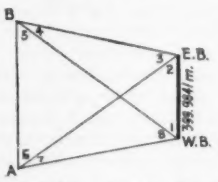
niers of an approximation of 20", were the only instruments available. The telescopes of these transits had a focal length of approximately 19 centimeters and eyepieces magnifying about 20 diameters. Targets were usually made of pine, 2 × 4 ins. and 6 to 8 feet long, covered with bands of black and white muslin and surmounted by black and white streamers to facilitate "picking them up."

Bases were measured with standardized steel tapes on practically level ground; slight inequalities were determined by a level line; spring balances and thermometers were used. Two or more measurements were made, tape lengths being marked on tops of stakes driven almost flush with the ground.

Greater accuracy than would ordinarily be expedient was advisable in this work, for the reason that it was in all cases to be duplicated by other engineers, and it was desired that an examination of the notes and computations should place the work above suspicion of being erroneous in case there was any discrepancy. The topographical (stadia) lines controlled had an average error of closure of 1-1500.

No information was available as to the accuracy attainable with small transits, and it was determined to employ the method used by the



Triangulation, El Chamizal De El Paso, Texas.

Angle.	Sets.	Value—Measured.	Value—Adjusted.	Correction.
1	2	58° 01′ 15.42″	58° 01′ 12.69″	— 2.73″
2	2	89° 04′ 04.58″	89° 04′ 01.59″	— 2.99″
3	2	24° 20′ 07.81″	24° 20′ 07.20″	— 0.61″
4	2	8° 34′ 42.50″	8° 34′ 38.52″	— 3.98″
5	2	82° 10′ 06.46″	82° 10′ 07.25″	+ 0.79″
6	2	64° 55′ 06.46″	64° 55′ 07.03″	+ 0.57″
7	2	9° 04′ 14.17″	9° 04′ 15.89″	+ 1.72″
8	2	23° 50′ 31.36″	23° 50′ 29.83″	— 1.53″
Total....		360° 00′ 08.76″	360° 00′ 00.00″	— 8.76″

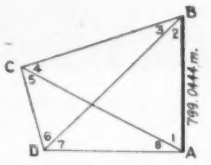
Instrument used, Buff & Berger transit No. 856, 6.5-in. circle, graduated to 20". Angles measured by two sets of 12 repetitions each (C. & G. Survey method). Length of base, 399.9841 meters.—Observer, P. D. Cunningham.

Note.—An excessive amount of smoke and haze made it very difficult to see the signals.

amount of accidental and constant errors. Sets of eight repetitions may be made in the same manner, but do not give results so satisfactory. One "set" as here used means twelve repetitions.

The small schemes of triangulation here dealt with covered from 15 to 120 sq. miles each; and the principal stations were usually connected by quadrilaterals, eight angles in each being measured by one to two sets of repetitions. Where two sets were made the "observed value" is the mean of the two. Because of the measurement of only eight angles each quadrilateral is complete within itself. The method of logarithmic residuals, given in Johnson's "Surveying," was applied to each quadrilateral in the adjustment of angular values and the results are identical with those to be obtained by the method of least squares It is therefore believed that some idea of the accuracy that may be obtained with the ordinary transit can be derived from the tables of quadrilateral angular measurements given herewith. Subsidiary angles are not given, because in simple triangles the excess or deficiency of the sum of the angles is not indicative of the accuracy of measurement.

Work was continued throughout the day regardless of atmospheric "boiling" and of wind, save on those occasions when stone cairns around the



Triangulation Across Las Sierras Sin Nombre, California.

Angle.	Sets.	Value—Measured.	Value—Adjusted.	Correction.
1	2	68° 41′ 01.04″	68° 41′ 00.40″	— 0.64″
2	2	94° 01′ 36.87″	94° 01′ 36.24″	— 0.63″
3	2	7° 28′ 59.06″	7° 28′ 59.13″	+ 0.07″
4	2	9° 48′ 23.75″	9° 48′ 24.23″	+ 0.48″
5	2	46° 34′ 07.61″	46° 34′ 07.85″	+ 0.24″
6	2	116° 08′ 28.54″	116° 08′ 28.79″	+ 0.25″
7	2	10° 58′ 33.33″	10° 58′ 32.50″	+ 0.83″
8	2	6° 18′ 51.25″	6° 18′ 50.86″	+ 0.39″
Total....		360° 00′ 01.45″	360° 00′ 00.00″	— 1.45″

Instrument used, Brandis transit No. 1586, 5.5-in. circle, graduated to 20". Angles were measured by two sets of 12 repetitions each (C. & G. Survey method). Length of base, 799.0444 meters.—Observer, P. D. Cunningham.

U. S. Coast and Geodetic Survey in repeating angles with repeating theodolites, a method which is possibly not generally known. What may be termed one set of repetitions consists usually of twelve angular measurements, six of the angle and six of its explement, all of which are cumulative in reading and should amount to six complete circuits of the horizontal limb, and this involves three readings of both the verniers after the original setting. The reversals of telescope positions are arranged to eliminate, as far as possible, the effect of changes of level, and the leveling screws should not be touched during the progress of a set. Care should be taken that all pointings be made by turning tangent screws *against* their opposing springs. The twelve measurements are indicated below:

	Telescope.	Measure.	
No. 1..	D	Angle.....	Read for approximate check value.
" 2..	D	"	
" 3..	D	"	
" 4..	R	"	
" 5..	R	"	
" 6..	R	"	Read; telescope is now on right hand target, the starting position for measurement of explement or 360° — angle.
" 7..	R	Explement.	
" 8..	R	"	
" 9..	R	"	
" 10..	D	"	
" 11..	D	"	
" 12..	D	"	Read.

In the reduction, the reading at the completion of (6) minus the original setting divided by six gives a value for the angle; the reading at (12) minus the reading at (6) divided by six gives a value for the explement. The sum of the values thus obtained (angle + explement) should be 360°, and the discrepancy is to be removed by applying equal corrections to angle and explement, from which result the values determined by the set. The difference between the final reading (12) and the original setting represents the cumulative tripod legs failed to give sufficient steadiness to make pointings possible.

Great delicacy of manipulation was found to be necessary, as a very slight awkward touch would spoil a set. It is believed that better results can be obtained when interdependent angles are measured by the same observer. The number of sets measured per day varied from 10 to 25; the time occupied in going from one station to another being an important factor. All computations were made in the field. This method of repetitions was found very satisfactory in azimuth determinations for the measurement of the angle between α Ursae Minoris and a mark placed approximately in the plane of the meridian.

SOME EXPERIMENTS ON BALL STEP-BEARINGS.*

By C. H. Benjamin, M. Am. Soc. M. E.†

Most of the published experiments on steel balls have merely shown the crushing strength of the balls under a dead load. In service balls do not fail in this way, and figures for the ultimate crushing strength are very misleading when used as a basis for designing bearings. Other experiments have been made on bearings running at a moderately high speed under light loads to determine the frictional resistance. It seemed desirable to make some further experiments, which should show the behavior of steel balls when running at various speeds and under gradually increasing pressures, to measure the horse power consumed and to determine the manner of failure. Investigations of this nature were made, under the direction of the writer, by senior students of the Case School of Applied Science during the years 1899-1900. The apparatus to be described was designed and built by Messrs. Grothe and Stephan, of the class of 1899, and a few experiments made. The work was continued the next year by Messrs. Hanlon and Harper, of the class of 1900. Some of the phenomena which developed in the course of these experiments were novel and of such interest as to warrant their publication.

The experiments so far made have been confined to thrust or step-bearings, and the apparatus used is shown in Fig. 1. The spindle A is held upright by the circular base K, which latter rests on the platform of a testing machine. On the spindle revolves the pulley B, driven by a belt from a Webber dynamometer used to measure the power transmitted. This pulley has ball-bearings above and below, precisely alike in character and size. Pressure is transmitted by the block G attached to the crosshead of the testing machine. The ring of balls to be tested runs between the two hardened and ground plates C and D, and are kept in place by the loose retaining rings E and F. The central well I is used for oiling the spindle, the radial holes JJ remove surplus oil by centrifugal force, and the packing rings H of vulcanized fiber prevent the oil from getting into the ball bearings. The hardened plates and the retaining rings could be changed at pleasure, and any size or numbers of balls used.

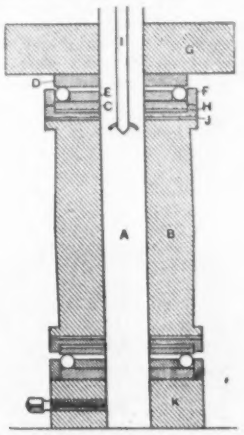


Fig. 1. Sectional Elevation of Machine for Testing Ball Thrust Bearings.

With this device it was possible to test step bearings with different sizes and arrangements of balls under any

Fig. 2. Fig. 3. Fig. 4.

Figs. 2 to 4. Forms of Plates for Ball Thrust Bearings.

desired pressure, and at the same time to measure the power consumed in driving. To establish a zero reading of power, the apparatus was driven without any load on the bearings, and the horse-power noted. In most of the experiments to be described a wooden pulley 14 ins. in diameter was clamped outside the pulley B to give more torque. The steel balls and the hardened plates were obtained of firms making a specialty of this kind of work.

TABLE I.—Showing Horse-power Required to Operate Ball Thrust Bearings of Various Kinds; Horse-power Quoted Includes Both Bearings:

Kind of Bearing.	Load, lbs.	Gross HP.	Net HP.
I. Plates—1°, 27 balls, ¼-in.	500	.1125	.0105
	1,000	.195	.093
	1,500	.204	.102
	2,000	.238	.136
	2,500	.332	.230
II. Plates—1°; 27 balls, ¼-in.; 2 3-16 circle.	500	.172	.070
	1,000	.216	.114
	1,500	.226	.124
	2,000	.480	.378
	2,500	.27 to .54	.17 to .44
	3,000	.533	.431
	3,500	.54 to .67	.44 to .57
	4,000	.82 to 1.0	.72 to .90
	4,500	.....	.....
III. Plates—1°; 26 balls, ¼-in.	500	.147	.045
	1,000	.198	.096
	1,500	.395	.293
IV. Plates—1°; 26 balls, ¼-in.	2,000	.257	.155
	2,500	.350	.248
	3,000	.418	.316
	3,500	.766	.664
V. Plates—1°; 19 balls, ¼-in.; 1 17-32 circle	500	.116	.014
	1,000	.140	.038
	1,500	.166	.064
	2,000	.317	.215
	2,500	.566	.464
	3,000	.55 to .83	.42 to .72
VI. Plates—1°; 20 balls, ⅜-in.	500	.213	.111
	1,000	.229	.127
	1,500	.247	.145
	2,000	.326	.224
VII. Plates—1°; 15 balls, ⅜-in.	500	.260	.158
	1,000	.321	.319
	1,500	.361	.259
	2,000	.660	.558
VIII. Plates—flat cage; 28 balls, ¼-in.	500	.137	.035
	1,000	.177	.075
	1,500	.198	.096
	2,000	.278	.176
	2,500	.354	.252
	3,000	.472	.370
IX. Plates—flat; 79 balls ¼-in.	500	.178	.076
	1,000	.35 to .56	.25 to .46
	1,500	.51 to 1.27	.41 to 1.17
	2,000	.....	.....
X. Three point, 18 balls, ⅜-in.	500	.185	.083
	1,000	.310	.208
	1,500	.448	.346
	2,000	.600	.598
	2,500	.790	.698

*Abstract of a paper presented at the Milwaukee meeting (May, 1901) of the American Society of Mechanical Engineers.

†Professor of Mechanical Engineering, Case School, Cleveland, O.

The first experiments were made with ¼-in. balls and flat plates, the speed being 375 revolutions a minute. As the pressure on the bearing was increased it was found that the balls exerted a considerable radial pressure on the outer retaining ring F, Fig. 1. Under a load of 2,000 lbs. this pressure was sufficient to cut a groove in the retaining ring. When the ring was allowed to revolve freely with the balls, each ball would indent the ring, and when the ring was removed thirty-one distinct dents could be seen at regular intervals, one for each ball. Thinking that this might be due to springing of the plates under pressure, we made the next lot of plates slightly concave at angles of 10′, 20′, 30′ and 40′, so as to bring the pressure of the rings directly above and below the ball circles. Instead of remedying the difficulty, this made it worse, the outward pressure being greater than before. At the speed used (375 revolutions per minute) the centrifugal force was not enough to account for the radial pressure, and the following was suggested as an explanation: A pressure of 2,000 lbs. and upwards on a bearing of this size (about thirty ¼-in. balls) is probably sufficient slightly to distort the balls and change each sphere into a partial cylinder at the touching points. While of this shape it would tend to roll in a straight line or a tangent to the circle, thus pressing against the outer retaining ring.

Acting on this suggestion we next had plates ground slightly convex, as shown in Fig. 2, the first angle tried being 20′, 40′ and then 1° were tried, with a decided improvement in the conditions, it being possible with the last angle to increase the pressure up to 3,000 lbs. without excessive friction. An angle of 1° 30′ being tried, the radial pressure again increased. It was supposed that the angle between the plates, now 3° was sufficient to cause the balls to be wedged out against the ring.

The subsequent experiments were made with plates having each an angle of 1°, or 2° between the plates. Circular tongs were made with which to grasp the retaining rings and determine when the radial pressure became excessive. It may be stated in general that under no circumstances was it possible to load a bearing of the size mentioned over 3,000 lbs. without seriously impairing its efficiency and durability. Now thirty ¼-in. balls should have (according to the results of experiments on direct compression) an ultimate combined strength of about 180,000 lbs., and a safe working strength of about 36,000 lbs. At one-twelfth of this working load the balls in such a bearing would lose all value as transmission elements. The retaining ring, when carried around by the balls, was always liable to rub against either top or bottom plate and cause abrasion and heating.

When the balls were retained in one circle, as shown in Fig. 1, the continual travel in one path soon grooved the plates enough to injure them. One plate developed radial cracks under this treatment, probably on account of the stretching of the outer circumference by the drawing effect of the balls. Different radii of ball circles and different sizes of balls were tried, as may be seen from the table.

One plate was broken into several pieces, the circle of balls having a diameter of about 2.25 ins. and the pressure being 4,000 lbs., or about 140 lbs. on each ¼-in. ball. In this case the plate had evidently been overheated in hardening. Several times balls were broken after running two or three hours under pressures varying from 3,000 to 3,500 lbs. or from 120 to 150 lbs. per ¼-in. ball. The heating due to the pressure against the retaining ring was sometimes sufficient to turn the balls blue. The fractured balls, however, showed no appearance of peeling or flaking, but were broken square across at or near a diameter.

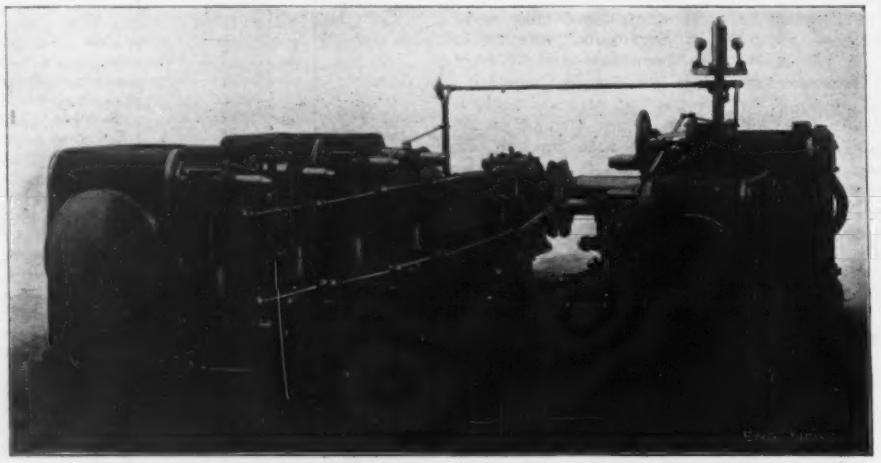


FIG. 1. FOUR-CYLINDER TRIPLE-EXPANSION STEAM ENGINE FOR CHINA.
The Lane & Bodley Co., Cincinnati, O.

In one series of experiments the whole space between flat plates was filled with ¼-in. balls put in indiscriminately. As might have been expected, the friction was enormously increased by this arrangement, and the belt slipped at a load of 2,000 lbs. See IX. in table.

The three-point bearing shown in Fig. 3 did not give as good results as the flat plates, but this was partly due to the fact that the plates in this case were not ground. See X. in table. We obtained the best results with a ring cage (Fig. 4) with holes so arranged as to give each ball a different path and thus distribute the pressure and wear on the plates. As flat plates were necessary with this arrangement, considerable outward pressure occurred. See VIII. in table.

In making the experiments from which the following table was compiled, the balls were carefully cleaned and although greasy were not oiled. The usual speed was about 260 revolutions per minute and the pressure was increased by additions of 500 lbs. until the belt slipped. The bearing was run for 10 mins. under each pressure. The gross horse-power was measured for each load by the dynamometer and the friction horse-power determined by running the bearing without pressure. The spindle A was thoroughly oiled, oil flying all the time from the radial holes J (Fig. 1). The plate, Fig. 5, shows graphically the gradual increase of horse-power with load. The double curve in the case of IX. shows the extreme variation in the power due to the accidental interferences of balls when running loose without rings or cages. No. VIII., the cage bearing, is seen to be the most uniform and the most satisfactory as regards power loss. The irregularities in most of the curves are due to the seizing of the outer ring by the balls, as before explained. Under heavy pressures and long continued wear a ball step bearing is a more uncertain quantity, unless so designed as to eliminate to the greatest extent possible the outward radical pressure of the balls. No pressure in any way approaching the crushing strength of the balls can be tolerated.

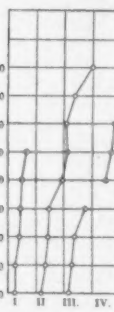


Fig. 5. Diagram Showing Horse-Power Required to Operate Ball Thrust Bearings of Various Forms.

DOUBLE-ECCENTRIC CORLISS ENGINES AND COMPRESSORS.—BENNETT AIR COMPRESSORS.

In the majority of the various designs of Corliss engines fitted with Corliss valves, the four valves are operated by rods from a wrist plate driven by a single eccentric. In some designs, only the admission valves are operated from the wrist plate, the exhaust valves being operated from a second eccentric. In the engine shown in Fig. 1, however, the wrist plate is dispensed with altogether, and the admission and exhaust valves are operated directly from two eccentrics. This engine was built by the Lane & Bodley Co. of Cincinnati, O., and the arrangement described is now its standard practice in engine construction except when customers specify the use of wrist plates.

The engine in question is a four-cylinder triple-expansion engine of 500 HP., built for a paper mill plant in China. This has a high-pressure cylinder, 16 × 42 ins.; intermediate cylinder, 26 × 42 ins.; and two low-pressure cylinders, 28 × 42 ins. The cylinders are arranged in two tandem pairs, the low-pressure cylinders being bolted to the heavy box castings which carry the slides and main bearings. The valves on each pair of cylinders are operated by lever arms attached to rods connected directly to two eccentric rods, one eccentric operating the admission valves and the other the exhaust valves. This arrangement allows of independent and close adjustment of the valves. The dash pots, instead of being placed on the floor, are attached to the cylinder casings, close under their respective valves, so that only short rods are required. These dash pots have no compression chambers, and they have very light parts and slight movement. It is claimed for this arrangement that the valves will seat properly with a lift of only ⅛-in., while when compression chambers are used a much greater lift is usually required, as with small lifts the valves are liable to stick until they are knocked home by the hook gear striking the rod. Oil pipes carry the waste lubrication from the upper valve stem packing to the lower valve stem packing. The slides are bored out and the casing in which they are formed is supported by a pedestal between the cylinder pedestal and the main bearing.

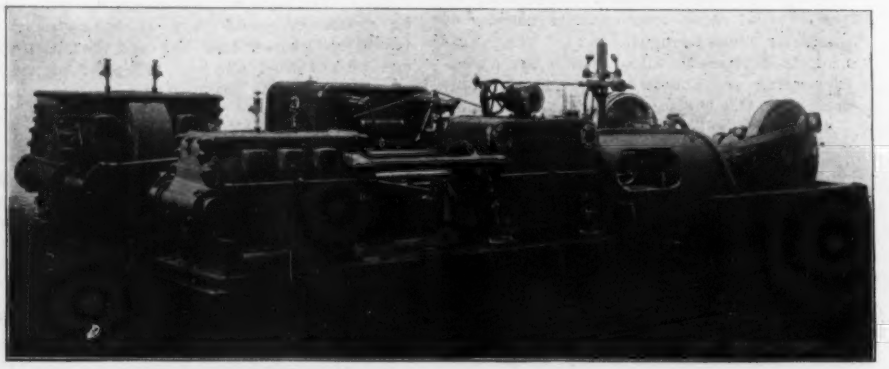


FIG. 2. CROSS-COMPOUND TWO-STAGE AIR COMPRESSOR FOR SOUTH AFRICA.
The Lane & Bodley Co., Cincinnati, O.

In Fig. 2 is shown a cross-compound two-stage air compressor built by the Lane & Bodley Co., for export to South Africa. The engine is rated at 600 HP., and has steam cylinders 20 × 48 ins., and 38 × 48 ins., while the air cylinders are 20 × 48 ins., and 34 × 48 ins. The air is delivered at a receiver pressure of about 80 lbs. The steam cylinders are bolted directly to the heavy frame casting in which are formed the bored slides, while the outer ends carry the shaft bearings. Owing to the dirty condition of the water available for cooling, the water jackets of the air cylinders have numerous hand-holes to allow of readily cleaning out the jacket chambers. The valves for each steam cylinder are operated by rods from a wrist plate driven

by a single eccentric, and from this wrist plate extends a rod operating the inlet and delivery valves of the air cylinders, as shown by the drawing in Fig. 3.

The air cylinders have the barrels and heads enclosed in accessible water jackets, and are fitted with the Bennett valve, which is a special feature of the compressors built by this firm, and is shown in Fig. 4. Across each cylinder head is formed a horizontal cylindrical chamber, in which oscillates a valve having inlet and discharge ports, there being only the one valve at each end of the cylinder. A single port furnishes communication between the cylinder and the valve chamber, but

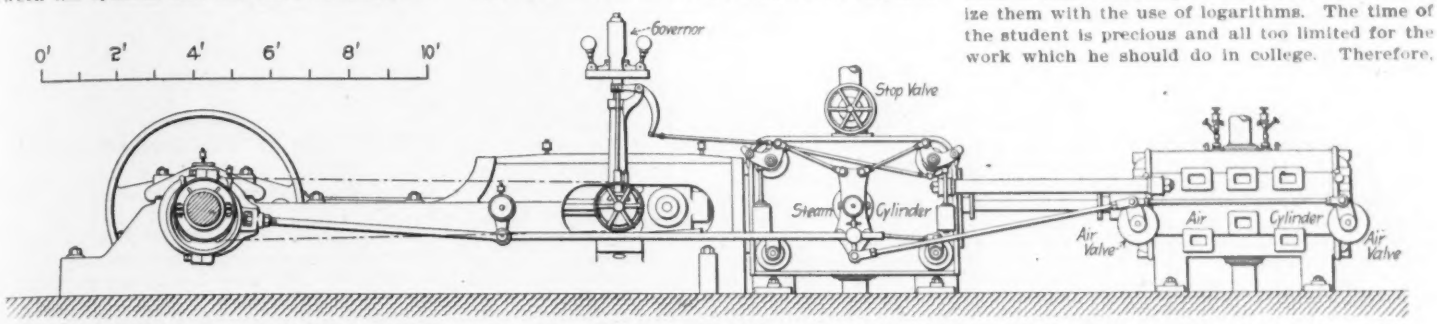


FIG. 3. ELEVATION OF LANE & BODLEY AIR COMPRESSOR, SHOWING VALVE GEAR.

the valve is provided with a series of openings, as shown. The arrangement gives a continuous admission and a variable discharge depending upon the pressure in the receiver, with instantaneous opening and closing of the valves at the end of the stroke.

THE USE OF CALCULATING MACHINES.

By Chas. A. Holden.*

There has been a query for some time in the writer's mind as to whether the Mannheim pocket slide-rule and other calculating machines are appreciated and used to as great an extent as they should be. To secure evidence on the subject, the following questions were prepared and 100 copies were sent to engineers, professors in engineering schools and business firms:

1. Do you use the slide-rule in your computations? (a) To what extent? (b) For what classes of computations? (c) What is your opinion of its applicability?
2. Do you use the Thacher calculating machine? (d) To what extent? (e) For what classes of computations? (f) What is your opinion of its applicability?
3. Do you use any other calculating machine? (g) To what extent? (h) For what classes of computations? (i) What is your opinion of its applicability?

In the questions sent to the engineering schools, the "you" in 1, 2 and 3 was changed to "your students." To these queries 75 replies were received, and they are summarized in the table given below.

The writer wishes to express his thanks to all who so kindly replied to his questions relative to the use of calculating machines.

Table Showing Use of Calculating Machines.

Used.	None.	Discouraged.	Little.	Much.	Constantly.	Total.
ENGINEERING SCHOOLS.						
Mannheim Slide-Rule.						
Number	3.0	1.0	8.0	3.0	9.0	24.0
Per cent.	12.5	4.2	33.3	12.5	37.5	100.0
Thacher Calculating Machine.						
Number	11.0	...	9.0	4.0	....	24.0
Per cent.	45.8	...	37.5	16.7	....	100.0
Other Calculating Machines.						
Number	11.0	...	....	....	....	....
Per cent.	45.8	...	....	....	....	....
ENGINEERS.						
Mannheim Slide-Rule.						
Number	10 0	...	13.0	....	15.0	38.0
Per cent.	26.3	...	34.2	....	39.5	100.0
Thacher Calculating Machine.						
Number	28.0	...	8.0	2.0	....	38.0
Per cent.	73.7	...	21.0	5.3	....	100.0
Other Calculating Machines.						
Number	31 0	...	....	....	....	....
Per cent.	81.5	...	....	....	....	...
BUSINESS FIRMS.						
Mannheim Slide-Rule.						
Number	11.0	...	2.0	....	....	13.0
Per cent.	85.6	...	15.4	....	....	100.0
Arithmometer.						
Number	9.0	...	....	....	4.0	13.0
Per cent.	69.2	...	....	....	30.8	100.0

*Instructor, Thayer School of Civil Engineering, Hanover, N. H.

The message of this paper is not *how* to use calculating machines, but to *use* them, and more particularly to use the Mannheim 10-in. slide rule. The method of mechanical manipulation and the principle upon which the rule is made, are well stated in "The Slide-Rule" by Mr. William Cox (Keuffel & Esser Co.), and, also, in the Engineering News—vol. 34, p. 340, and vol. 25, p. 5. The replies to the above questions showed quite a general haziness as to the extent to which the slide-rule can properly be used. Many stated that it is good as a check, or, where extreme accuracy is not required, but without a definite idea as to the relation between the accuracy of the rule and the data of most engineering problems. Ordinary solutions with the rule can be made within one-tenth of 1%, and the most complicated should give a result within three-tenths of 1%. Upon this point some stated that the rule was accurate to only 1%. From eight-tenths of 1% to 1% applies to the top scales of the rule; but they should not be used when the best work possible with the rule is desired; such work requires the lower scales. Otherwise the rule might as well be only 5 ins. long instead of 10 ins. Taking the average accuracy of the slide-rule as two-tenths of 1%, we may use it to solve all problems in which the data is of no greater accuracy. Little time is required to think of a host of such problems: Moments of beams, stresses in all classes of structures, weights for estimate, areas in many surveys, reductions in stadia work, computation of earthwork, machine design, contents of scows in dredging, hydraulics, studies relative to the purification of water and sewage—in fact, for all preliminary and very many final estimates, perhaps three-fourths of the computations ordinarily required of an engineer. If, then, there is so large a field for the use of the slide-rule, why is it not used to a greater extent? The reply of one who has "but recently taken up the use of the slide-rule" is:

> I can fully recommend the use of the slide-rule for a great variety of work, especially where several operations are required in securing the result. My reason [better say excuse] for not taking up its use earlier is that I did not learn the rule in school and to break in the rule on work actually on hand—usually rush work—means temporary delay. The slide-rule should be mastered in school.

Let not temporary delay prevent permanent gain and thus cause permanent delay!

How do the engineering schools stand as to teaching the use of the slide-rule? As will be seen in the above table, about 50% are remiss in this duty. One of the great advantages in the use of the slide-rule with students is that it delivers them from the habit of attempting that "fictitious accuracy" so often seen in engineering computations. It has been the writer's practice, when teaching in a four-years' course, to require constant use of the slide-rule by the students, beginning with the Sophomore year—the computations in the Freshman year being used to familiarize them with the use of logarithms. The time of the student is precious and all too limited for the work which he should do in college. Therefore, any means by which the drudgery and weariness of computations can be satisfactorily lessened should be employed. So far as possible, all practicable methods of work should be taught in school, where the student has some one to check his work and assist him over difficulties. In the business world his time is fully occupied and he is loth to try new methods, where he must have confidence in the result and be responsible for it. A professor in one college wrote: "In my judgment, a technical school has not done its full duty by its students unless they have been so drilled in the use of the slide-rule that they turn to it on all occasions."

The managers of business firms, in a few instances, are aware of the benefit to be derived from the use of calculating machines and are adopting those adapted to their work. In one case computations on accounts were done with a Thacher machine, "doing in three or four days what had usually taken three weeks." There are yet very many who can with great advantage adopt calculating machines for their work—such as assessors, contractors, employees in commercial houses, et cetera.

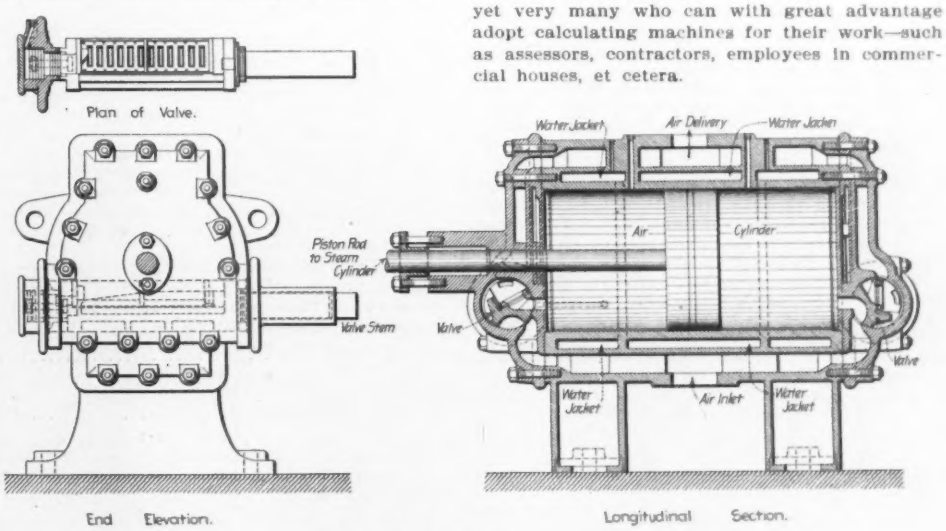


FIG. 4. DETAILS OF AIR CYLINDER AND BENNETT VALVE.

In conclusion, if one who has never used a slide-rule will spend a little time working out simple problems under the direction of some one who is familiar with the use of the rule, or in conjunction with Mr. William Cox's "The Slide-Rule," already referred to, and will then study thoughtfully and analytically to determine for what problems he finds the rule adapted, there will be many more constant users of the slide-rule, and the statement, "its comparatively infrequent use is surprising," will no longer be heard.

TEST OF AN HYDRAULIC AIR COMPRESSOR.*

By William O. Webber, M. Am. Soc. M. E.†

Some tests made September 10, 1899, of an hydraulic air compressor operating at the plant of the Dominion Cotton Mills Co., Ltd., at Magog, P. Q., Canada, gave the results which are recorded in the following paper. These tests were made on a hydraulic air compressor known as the Taylor compressor. This compressor embodies the principles of the old trompé used in connection with the Catalan forges some centuries ago, modified according to principles which were first described by Mr. J. P. Frizell, in an article in the "Journal of the Franklin Institute," September, 1880, which was further improved by Charles H. Taylor, of Montreal, and patented by him July 23, 1895. It consists principally of a down-flow passage having an enlarged chamber at the bottom and an enlarged tank at the top. A series of small air pipes project into the mouth of the water inlet and the large chamber at the upper end of the vertically descending passage, so as to cause a number of small jets of air to be entrained by the water. At the lower end of the apparatus, deflector plates in connection with a gradually enlarging section of the lower end of the down-flow pipe, are used to decrease the velocity of the air and water, and cause a partial separation to take place. The deflector plates change the direction of the flow of the water and are intended to facilitate the escape of the air, the water then passing out at the bottom of the enlarged chamber into an ascending shaft, maintaining upon the air a pressure due to the height of the water in the uptake, the compressed air being led on from the top of the enlarged chamber by means of a pipe. The general dimensions of the compressor plant are:

Supply penstock	60 ins. diam.
Supply tank at top	8 ft. diam. × 10 ft. high.
Air inlets (feeding numerous small tubes)	34 2-in. pipes.
Down tube	44 ins. diam.
Down tube at lower end	60 ins. diam.
Length of taper in down tube, changing from 44 ins. to 60 ins. diam.	20 ft.
Air chamber in lower end of shaft	16 ft. diam.
Total depth of shaft below normal level of head water	About 150 ft.
Normal head and fall	About 22 ft.
Air discharge pipe	7 ins. diam.

It is used to supply power to engines for operating the printing department of the cotton mills.

There were three series of tests conducted to determine the efficiency of the compressor, viz.: (1) Three tests at different rates of flow of water, the compressor being as originally constructed. (2) Four tests at different rates of flow of water, the compressor inlet tubes for air being increased by 30 ¾-in. pipes. (3) Four tests at different rates of flow of water, the compressor inlet tubes for air being increased by 15 ¾-in. pipes.

The water used on the tests was measured by a weir 10 ft. in width, three hook gages being employed for determining the head. The compressed air delivered was measured by air meters, properly calibrated. The contained moisture in the air was measured by carefully standardized instruments. The head of water, condition of the air, pressures, temperatures, and quantities were read at five-minute intervals. The tests extended over a period of two days, and the results were as shown by Table I.:

Test I., when the flow was about 3,600 cu. ft. per minute, showed a decided economic advantage by the use of 30 ¾-in. extra air inlet pipes, the efficiency increasing from 56.8% for the original setting to 64.4% when modified. Test II. shows, when the flow of water is about 4,200 cu. ft. per minute, that the economy is highest when only 15 extra air tubes are employed, the efficiency increasing from 60.3% for the original setting, to 70.7% as modified. Test III. shows, when the flow is about 4,000 cu. ft. per minute, that there is no economic advantage by increasing the air inlet area in this particular installation. Test IV. shows that a flow of 5,000 or more cu. ft. of water is in excess of the capacity of the plant. These four tests may be summarized as follows, (Table II.):

The tests show: (1) That the most economic rate of flow of water with this particular installation is about 4,300 cu. ft. per minute. (2) That this plant has shown an efficiency of 70.7% under such a flow, which we consider excellent for a first installation. (3) That the compressed air contains only from 30 to 20% as much moisture as does the atmosphere. (4) That the air is compressed at the temperature of the water.

*Abstract of a paper presented at the Milwaukee meeting (May, 1901) of the American Society of Mechanical Engineers.

†53 State St., Boston, Mass.

TABLE II.—Summary of Tests of Hydraulic Air Compressor.

Items.	Flow of water cu. ft. per min.	Efficiency, per cent.
Original setting	3,772	56.8
" "	4,066	60.3
" "	4,408	64.5
Air inlets increased by 15 ¾-in. pipes	3,507	55.2
" " " " "	4,292	70.7
" " " " "	4,700	62.2
" " " " "	5,058	63.3
" " " 30 ¾-in. "	3,628	64.4
" " " " "	4,310	61.3
" " " " "	4,600	62.0
" " " " "	5,345	55.4

The results of these tests, together with two others made by Professor McLeod on the same plant on August 13, 1896, in its original condition, are shown on the accompanying diagram.

In the tests at Magog we recovered 81 HP., using an old Corliss engine without any changes in the valve gear as a motor; this would represent a total efficiency of work, recovered from the falling water, of 51.2%. When the compressed air was preheated to 267° F. before being used in the engine, 111 HP. was recovered, using 115 lbs. coke per hour, which would equal about 23 HP. The efficiency of work recovered from the falling water and the fuel burned would be, therefore, about 61½%. On the basis of Professor Riedler's experiments, which require only about 425 cu. ft. of air per brake horse-power per hour, when preheated to 300° F. and used in a hot-air jacketed cylinder, the total efficiency secured would have been about 87½%.

The second compressor on the Taylor principle is located on Coffee Creek, to the south of Ainsworth, British Columbia. The available head of water is 107.5 ft. The

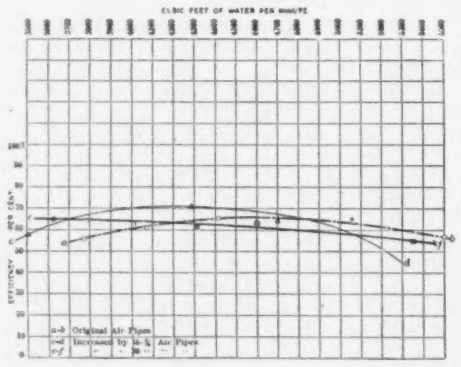


Diagram Showing Results of Tests of Hydraulic Air Compressor for Dominion Cotton Mills Co., Magog, Quebec.

down-flow pipe is 33 ins. in diameter. The shaft is 32 sq. ft. area and 210 ft. deep. The maximum volume of water is 4,200 cu. ft. per minute, and would represent, at 71% efficiency, 587 HP. This compressor is expected to utilize about 5,100 cu. ft. of free air per minute, or 734 cu. ft. of compressed air at 87 lbs. pressure, and give an air motor output of 360 HP. It is possible, however, that this plant may not give as high percentages as this, as the water passages are of smaller areas than those at Magog. Three other plants are now under construction, one at Peterborough, Ont.; one at Norwich, Conn., and one in the Cascade Range, Washington.

The plant at Peterborough, Ontario, for the Government of the Dominion of Canada, is to be used in connection with one of the locks on the Trent Valley Canal, the chief dimensions being as follows:

Head of water	14 ft.
Gage pressure	25 lbs.
Diameter of compressor pipe	18 ins.
Diameter of shaft	42 ins.
Depth below tail-race	64 ft.

The whole plant is enclosed in the masonry wall of the lock, the usual rock chamber in the bottom of the shaft being built in concrete, and only a few feet below the water level of the lock.

At Norwich, Conn., at what is known as the Taftville Privilege on the Quinebaug River, the plant will give 1,365 HP. of air at a pressure of 85 lbs. per sq. in.

Head of water	18½
Diameter of shaft	24
Diameter of pressure pipe	13
Depth of shaft	208

The air will be transmitted a distance of four miles with a loss in transmission not exceeding 2%, through 12-in. pipe, which will be laid with flanged joints and rubber gaskets.

The plant which is being constructed in one of the canyons of the Cascade Range of mountains in the State of Washington will give 200 HP. of air at a pressure of 90 lbs. per sq. in.

Head of water	45
Diameter of compressor pipe	3
Diameter of up-flow pipe	4 ft. 9½

There is no shaft, as the apparatus is constructed against the vertical walls of the canyon. The capacity of the plant is based on 2,000 miner's inches of water, equal to 55 cu. ft. per second. The total height of this apparatus is about 260 ft.

SEWER GAGINGS AT SHEBOYGAN AND MILWAUKEE, WIS.*

By Richard T. Logemann† and Richard A. Nommensen.‡

The available information for the economic designing of sewers, both for storm and for dry weather flow, is not of a very extensive nature; in fact the importance of such information has been very slow in becoming recognized, and it is only within the last comparatively few years that the subject has been given attention by our municipal engineers.

The practice most generally followed in designing a sewerage system for dry weather flow has been to utilize records from the rate of water consumption, where such were to be obtained, or else to assume a rate of consumption high enough to be within safe limits. On the assumption that the amount of sewage must be equal to the amount of water consumption, this method will give results that are applicable and sufficiently accurate for all practical purposes. But the rate of consumption and the rate of sewer discharge are not always the same, and to find some relation between the two quantities is of much importance.

All the available information on this subject is well collected and summarized in Mr. Folwell's recent book on "Sewerage," and also in a thesis by two students of the Iowa Agricultural College,§ and in order to present it in shape for comparison and use, we give a synopsis of the experiments in Table I.

DRY WEATHER FLOW AT SHEBOYGAN, WIS.

The experiments on dry weather flow were made in the city of Sheboygan, Wis., a city of 23,000 inhabitants. The district upon which the gagings were made comprises an area of 90 acres and represents a strictly residential portion of the city. Its size is such that complete statistics necessary for our computations could be conveniently obtained by a house-to-house canvass, the results of which are shown in Table II. In determining the sewage discharge per capita, the number of persons using the sewer connections (728) was taken as the total population contributing to the sewers.

The sewage is discharged through a 30-in. sewer

*Abstract of a thesis submitted for the degree of Bachelor of Science in Engineering at the University of Wisconsin, Madison, Wis., 1899.

†Scherzer Rolling Lift-Bridge Co., Monadnock Block, Chicago.

‡C., M. & St. Paul Ry., Milwaukee, Wis.

§See Engineering News, Feb. 27, 1896, for the thesis. Table I., herewith, is taken from the article named, but the last column was added by the authors of this thesis. —Ed.

TABLE I.—Results of Tests made at Magog, Can., Sept. 10, 1899, of a Hydraulic Compressor.

Items.	Test I. Original.	Test I. Inc'd by 15 ¾-in. pipes.	Test I. Inc'd by 30 ¾-in. pipes.	Test II. Original.	Test II. Inc'd by 15 ¾-in. pipes.	Test II. Inc'd by 30 ¾-in. pipes.	Test III. Original.	Test III. Inc'd by 15 ¾-in. pipes.	Test III. Inc'd by 30 ¾-in. pipes.	Test IV. Inc'd by 15 ¾-in. pipes.	Test IV. Inc'd by 30 ¾-in. pipes.
	Compressor head air inlets—										
Flow of water, cu. ft. per minute	3,772	3,507	3,628	4,066	4,292	4,310	4,408	4,700	4,600	5,058	5,345
Available head in ft.	20.538	20.119	19.997	20.348	19.509	19.578	19.929	19.309	19.411	18.747	19.309
Gross water, HP.	146.3	132.2	136.9	156.2	158.1	159.4	165.8	171.4	168.6	179.1	194.9
Cu. ft. air delivered at atmospheric pressure per min.	864	765	901	967	1,148	998	1,091	1,103	1,070	1,165	1,115
Pressure of air at compressor, lbs.	51.9	51.9	53.7	53.2	53.3	53.7	53.7	52.9	53.6	53.3	52.7
Atmospheric pressure, lbs.	14.51	14.42	14.47	14.51	14.41	14.45	14.51	14.40	14.44	14.44	14.40
Effective work done in compressing air, HP.	83.3	73.5	88.2	94.3	111.74	97.7	107	106.8	104.5	113.4	107.8
Percentage of efficiency of compressor.	56.8	55.5	64.4	60.3	70.7	61.3	64.5	62.2	62	63.3	55.4
Temperature of external air, deg. Fahr.	68.3	64.7	57.7	66.4	65.2	61.4	59.7	65	61.8	64.2	65.2
Temperature of water and compressed air, deg. Fahr.	66	66.2	65.5	66.4	66.5	65.5	67	66.5	66	66	66.5
Ratio of water to recovered air by volumes.	4.37	4.58	4.03	4.20	3.74	4.32	4.04	4.26	4.30	4.34	4.79
Moisture in external air, p. c. of saturation.	61	63	77.5	71	68	65	90	60.5	68	63	63.5
Moisture in air after compression, p. c. of saturation.	51.5	39	44	38.5	35	31	29	31.2	38	30	33.5

directly into Lake Michigan, thus affording a good opportunity for measuring the discharge by means of a weir. Fig. 1 shows the position and general arrangement of the apparatus. The box was built perfectly watertight, 6 ft. long, 2 ft. deep and 2 ft. wide. An 8-in. weir was cut in the outlet end of the box, its outer edges beveled and its inner edges lined with a strip of sheet iron, thereby insuring complete end contraction.

The variations of the head upon the weir were recorded automatically on a cylindrical drum of 12 ins. circumference, revolving once in 12 hours, placed upon the box at a distance of 2 ft. from the weir. The pencil, which was pressed against the drum by a small spring, was connected with a small float, 10 ins. diameter and 2½ ins. deep, by a light wooden vertical rod, the fluctuations of the head being thus recorded directly on the drum. The pencil was prevented from moving laterally by two vertical uprights which guided the case in which the pencil was held. The float was protected from obstructions, debris and slight countercurrents by a perforated cylindrical casing. The entire apparatus was protected from snow and wind by a canvas covering.

The gagings were made during the winter of 1898-99, at two different times. One 24-hour test was made Jan. 2 and another continuous week's record was obtained during the week of March 1 to 8, inclusive. Some very extraordinary results were obtained from the curves of the week's gagings in March, the rate of discharge per capita being abnormally great. These results, however, can be easily accounted for by the inclemency of the weather. To guard against the freezing of the pipes during this extremely cold period, the water company authorized its consumers to keep up a continuous flow of water from the taps. In consequence thereof the discharge through the sewers was almost as great during the night as during the day, which fact is well shown by the curves. (As the diagrams for daily flow show depths in inches only, we have reproduced, in Fig. 2, only the two extremes, namely, Jan. 2-3 for minimum, and March 2-3 for maximum flow.—Ed.) The average discharge per capita during that extraordinary week was 408 gallons per day. As far as the writers are able to ascertain there is no case on record of similar experiments that gives such a high rate of discharge. The single test of Jan. 2 was made under more favorable climatic conditions, and the results derived therefrom compare more favorably with those obtained from experiments made elsewhere.

The water consumption of the city for several weeks during the cold spell was also double the normal amount. Meters are not used in the city

Fig. 1. View of Sewer Gaging Weir on Automatic Recording Apparatus, Sheboygan, Wis.

and as a result we find even the normal consumption of water amounts to 100 gallons per day per capita for the entire population of the city, or about 200 gallons per consumer per day. The writers were, therefore, unable to ascertain accurately the amount of water consumed by the population living in the district upon which the experiments were made. That this district used more per consumer than the average of the entire city is plainly shown by the fact that the sewage discharge per contributor was actually greater than the average consumption per taker of the city upon several days during March. Although there is a seepage of ground water into the sewers it could not have been great enough, especially at this time of the year, to increase the sewage discharge so much above the average water consumption. If these statements mean anything, they at least show that the method of approximating the amount of water consumption in any district by proportioning the amount according to the number of taps, a method employed to a great extent, will often lead to very erroneous results. No definite relation could, therefore, be obtained between the water consumption and the sewage discharge.

TABLE I.—Sewer Gagings at Various Places in the United States and Canada.

Location of sewers.	Year.	No. gaging.	Population. Total.	Population. Tributary.	Sewage flow, galls. per min. Minimum.	Sewage flow, galls. per min. Average.	Sewage flow, galls. per min. Maximum.	Ratio of maximum to average.
Compton Ave., St. Louis, Mo.	1880.	6 days.	8,200	600	88	132	203	1.54
College St., Burlington, Vt.	1880.	13 hrs.	.....	325	65	115	140	1.22
Huron St., Milwaukee, Wis.	1880.	....	4,030	3,174	..	..	120	....
Poughkeepsie, N. Y.	1880.	....	.....	301	..	265	..	....
Memphis, Tenn.	1881.	1 day.	35,000	20,000	61	..	140	....
Thirteen sewers, Providence, R. I.	1884.	....	.....	...	..	78	..	....
Kalamazoo, Mich	1885.	1 day.	.....	...	224	254	287	1.12
Sixteen sewers, Toronto, Can.	1891.	3 days.	.....	168,081	53	87	316	3.63
Insane Hospital, Weston, W. Va.	1891.	2 "	.....	1,000	40	91	151	1.66
Atlantic City, N.	1892.	....	Not stated.					
Schenectady, N. Y.	1892.	1 day.	Not stated.					
Main building, Iowa Agricultural College	1894.	7 days.	492	289	0	32	77	2.40
Des Moines, Ia., east side.	1895.	16 "	13,100	8,100	22.5	74	142	1.90
Des Moines, Ia., west side	1895.	13 "	26,000	19,400	23.2	66	175.3	2.65
Plainfield, New Jersey	1896.	....	.....	...	..	..	..	....
Sheboygan, Wis.*	1898.	1 day.	959	728	58	70	112	1.60
Sheboygan, Wis.*	1898.	7 days.	959	728	186	207	238	1.15

*These two lines have been computed and added by the editor, from the figures given by the authors.

The formula $D = C \frac{2}{3} B \sqrt{2G} H^3$, was used in figuring the discharge, in which D = Discharge in cubic feet per second; C = Coefficient obtained from Merriman's Hydraulics; B = Width of weir in feet; G = 32.16; and H = Head of water on weir in feet. The values of c used in the computation were 0.601 for a head of 4 to 4½ ins., and 0.611 for a head of 2½ ins. The coefficient was checked by allowing the water to run into a box of known contents and noting the time with a stop watch, that it required to fill the box, at the same time reading the head of water upon the weir.

The records of the heads for the successive days of the experiments are presented in the curves, from which curves the average, maximum and minimum discharge have been calculated and the results presented in Table III.

The average rate of flow during the week in March was 408 gallons per capita, as compared with the average flow of 153 gallons for the single day in January. The maximum rate of flow in March was 541 gallons per capita, the minimum was 345 gallons per capita.

The curve of March 5-6 showed a considerable rise during the afternoon, which was due to the surface water from melting snow. The average, maximum and minimum heads for this curve were taken, excluding that part of the curve from noon to 6 p. m., when the surface water was contributing. The maximum rate of flow on Jan. 3 occurred at 9.40 a. m.; the minimum at 3 a. m. Although there was only a slight hourly variation in the rate of discharge during the week in March, the maximum occurred during the forenoon and the minimum between the hours of 1 and 4 a. m. on each of the days.

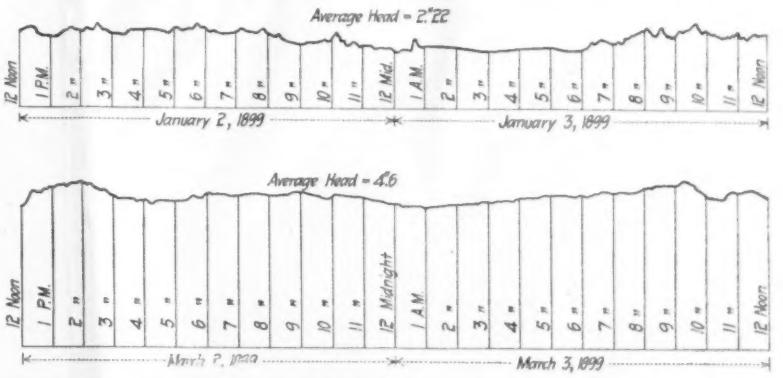


FIG. 2. DEPTH OF DRY WEATHER SEWAGE FLOW AT SHEBOYGAN, WIS., JAN. 2-3, AND MARCH 2-3, 1899.

(The excess in March was due to letting water run to prevent freezing.)

STORM WATER FLOW AT MILWAUKEE WIS

Having thus presented the results of our experiments on dry weather flow, we will now consider our experiments on storm water flow.

In determining the size of sewers to carry off the rainfall, recourse has been had to the results of a few very indefinite experiments on storm water flow, made in some of the London sewers in 1857. From these experiments resulted a general rule, that has been accorded almost universal acceptance for a long time, of assuming that 50% of the rain falling during a storm will reach the sewers, while the remainder is accounted for by direct percolation into the soil, and by evaporation. Many systems, both good and bad, have been designed in this manner, and while a rule of some kind is better than no rule at all, engineers are beginning to realize the necessity of a more scientific method. Whether the relation of rainfall to discharge can be satisfactorily expressed by a scientific formula is still an unsettled question. The Hawksley formula is an attempt to express, in mathematical terms, the relation between rainfall and size of sewers, assuming that 50% will be discharged. The application of Hawksley's formula has in many cases resulted in the flooding of sewers. However, it is not the object of this article to enter upon the discussion of the merits of this formula, nor that of the many others that can be found in text-books. The writers merely desire to add their results to the small amount of data now available.

The experiments on storm water were made by means of an automatic gage in an 8-ft. sewer in the city of Milwaukee during the summer of 1898 and extended over a period of six weeks. Fig. 3 shows the apparatus used and the connection of the different parts. The level of the water in the sewer was recorded on a cylindrical drum by means of a reducing lever at the ratio of 1 to 10.

TABLE II.—Census of Gaged Sewerage District at Sheboygan, Wis.

	No.	Population.	P. ct. of total pop'n.
Houses	105	959	....
Water connections	145	777	81.5
Sewer connections	136	728	75.9
Total number bath tubs	81	401	41.8
Total number of water closets	97	488	50.9
Total length of sewers in miles	2.59	...	....

TABLE III.—Dry Weather Flow of Sewage in Gallons per Contributor at Sheboygan, Wis., Jan. 2-3, and March 1 to 8, 1899.

Discharge.	Day ending at noon on— Jan. 3.	March 2.	3.	4.	5.	6.	7.	8.	Av'ge for week.†
Average	153	417	447	397	394	397	415	388	408
Maximum	222	485	541	475	460	465	447	436	471
Minimum	114	364	420	364	352	345	364	364	368
Av. consumpt'n*	210	347	346	338	331	334	373	349	345

*Average water consumption for whole city (rate per consumer) is estimated at about half this amount.—Ed.
†This column has been added by the editor.

The cylindrical drum referred to was the same as that used in the experiments on dry weather flow. The float used was a 10-in. spherical shell of galvanized sheet-iron, with a bore through the center to allow it to move up and down on a vertical iron rod, which was fastened securely at both the bottom and roof of the sewer. The weight of the connecting rod and of the lever was carefully counterbalanced, and the apparatus thus made quite sensitive to changes in the level of the water. The paper on the drum was removed from day to day, or as the occasion required, and thus a continuous record was obtained.

The total area of the drainage district is 1,138 acres, and of this about 18.5% is street area. It is almost exclusively a residential portion of the city, with the exception of a few business blocks. It is well built up and represents a fair average of the residential district. A number of the streets have block pavements, some are macadamized, but the greater portion are good gravel and earth roadways. Sewers are laid in every street, the main sewer, in which the apparatus was placed, being laid on a continuous 0.25% grade. Regarding the laterals, it may be said that they conform fairly well with the grade of the main sewer.

Complete records of the rainfall were obtained through the courtesy of the U. S. Weather Bureau, which has placed one of the their standard, automatic, autographic gages in the city. A check upon these records was obtained by a comparison with the city rain gage, which was read by means of a graduated stick at the beginning and at the end of a rain, and at times at which there was any noticeable change in the rate of rainfall. The accuracy of such records depends, of course, largely upon the judgment of the observer, who is, in this case, an employee of the city water-works department. These two gages are placed at a distance of about 2 miles from each other, and 1 to 2 miles from the drainage district. They agreed fairly well, at least on those rainfalls that are used in this discussion, and the writers feel safe in saying that although the gages were some distance from the district, the rainfall was uniform over the entire section, and fell with the registered intensity.

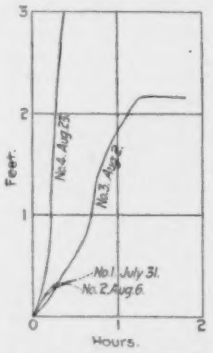


Fig. 4. Gaging Showing Depth of Storm Water Flow in Sewer at Milwaukee, Wis.

Only four curves are presented from the entire six weeks' gagings, reductions of which are shown in Fig. 4. The difficulties and accidents attending experiments of this kind will readily explain why more satisfactory results were not obtained. Some of the curves also showed results that were connot presented here. The curves were evidently obtained under conditions when the rainfall in the district was not the same as the registered intensity at the gages. Kutter's formula was used in the computations, and the coefficient was checked by means of a number of float readings during dry weather flow. From Kutter's formula the value of c is found to be 74 for a depth of flow of 7½ ins. From a formula in Merriman's Hydraulics, $c = c' - (\frac{d}{2} - d')$, in which c' is the coefficient when half full, D is the diameter of the conduit, and D' is the depth of water in the sewer in feet; the value of 74 was obtained for a depth of flow of 7½ ins. The average velocity obtained from ten different float readings for a depth of 7½ ins. was 2.2 ft. By substituting this in the formula, $v = c\sqrt{RS}$, knowing R = hydraulic mean S = slope, and v, c was again found to be 74. This shows that the value of c obtained from Kutter's formula can be correctly applied in these experiments.

Curve 3, in Fig. 4, was obtained under almost ideal conditions, and will be described first and

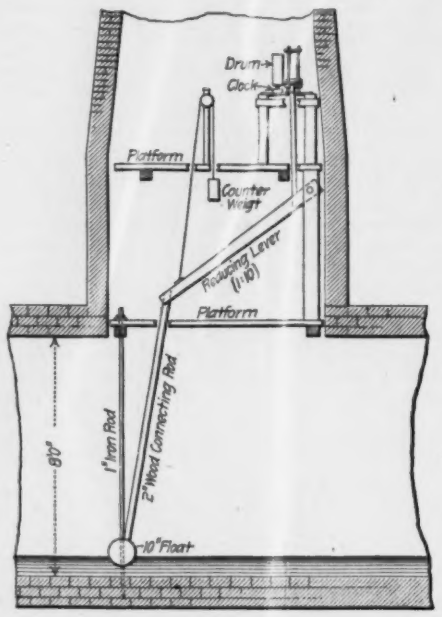


Fig. 3. Automatic Registering Apparatus for Gaging Sewage at Milwaukee, Wis.

used as a means of explaining the others. The automatic rain gage recorded, on this day, a rain of 85 minutes' duration at the fair uniform rate of 0.28 in. per hour. At the end of this time the rain changed to an intensity of 0.15 in. per hour, and continued for some time at this rate. An examination of the curve will show that the water in the sewer rose quite uniformly until the discharge reached a maximum, and then the curve continued in a horizontal line until the rain relaxed, when it started to go downward. This maximum discharge was reached when the entire area was contributing, and from the curve this is seen to have required 75 minutes. The percentage of rainfall flowing off at the time of maximum discharge was 20%.

The time that it takes for the entire area to be contributing at any point during a rain varies inversely (though not proportionally) as the intensity; that is, the greater the intensity the less the time. The method that was employed for obtaining the time that is required for the entire area to be contributing at the gage was as follows: The velocity at maximum discharge, in the curve just discussed, was 4.5 ft. per sec., and the depth of flow in the sewer was 34% full. Assuming the same relative depth of 34% throughout the entire length of the sewers, we obtain from Kutter's formula a velocity of 1.5 ft. per sec. at the extreme upper end. The size of the sewer at the upper end is 12 ins. diameter, and the total distance from the gage is 13,000 ft. Thus, with an average velocity of 3 ft. per sec., the time required for the entire area to be contributing is 72.2 minutes, as compared with 75 minutes obtained from the curve.

In the other curves, Nos. 1, 2 and 4, the maximum discharge was reached before the entire area was tributary, and in these cases it was necessary to figure the percentage of area contributing at the maximum discharge. In regular oblong-shaped areas, the amount of tributary area for a given rainfall is to the time for the total area to become tributary, with the same relative depth of flow throughout the sewer as the maximum depth for the given rainfall. The time for the total area to become tributary can be computed, as stated heretofore, and the time of maximum discharge is

TABLE IV.—Gagings of Storm Water Flow of Sewage at Milwaukee, Wis., in the Summer of 1898.

Date, 1898.	July 31.	August 6.	2.	23.
Amount rainfall, ins...	0.05	0.043	0.40	0.30
Duration of rain, mins.	30.0	15.0	85.0	25.0
Intensity, ins. per hour	0.1	0.172	0.28	0.72
Velocity, flow,* ft. pr sec.	2.85	2.80	4.50	6.03
Area cross-sect'n, sq. ft.	3.57	3.40	15.30	24.03
Discharge, cu. ft. pr sec.†	6.42	5.72	65.07	116.85
Time,‡ minutes	89.0	100.0	75.0	67.0
Area contributing at max. discharge, %..	43.0	15.0	100.0	37.0
No. acres contributing at maximum discharge.	490.0	170.7	1138.0	421.0
Rain flowing off,* %...	13.0	19.0	20.0	38.0
Same from Hawksley, %	16.2	19.6	66.6	63.4
Same from Adams, %..	15.9	12.6	75.8	73.7

*Velocity of flow at maximum, from experiment. †From experiment. ‡In minutes for whole area to be tributary.

taken from the curve. From this proportion the percentage of area contributing was obtained. In curve No. 4, the intensity of rainfall changed from 0.72 in. per hour after 25 minutes duration, to a rate of 2.48 ins. per hour, lasting for a period of 35 minutes, increasing the discharge to such an extent that the entire sewer was soon filled to overflowing. The apparatus broke with this change of rainfall. The last series of figures shows the results obtained when the sewer was flowing full. The percentage of rainfall flowing off for each of these rainfalls, as shown in the table, represents the percentage of rainfall flowing off of the tributary area. Table IV. shows the results of our experiments.

The discharges for these different rainfalls was computed from the Hawksley and Adams formulas, and were plotted together with the actual discharge as obtained by the experiment. An examination of these curves, Fig. 5, shows that the discharge as figured from the formulas does not agree with the discharge obtained from the experiments as the intensity becomes greater. Similar results are reported by Mr. Grover, in the account of his investigations on "The Storm Water Flow of the Sewers of Omaha" (Vol. XXVIII., Trans. Am. Soc. C. E.); and also by Mr. Emil Kuichling, in his article on "Relations between Rainfall and Discharge of Sewers" (Vol. XX., Trans. Am. Soc. C. E.). The above are all the available records on this subject which were accessible to the writers. These references treat the subject very comprehensively, and to enter into a further discussion of

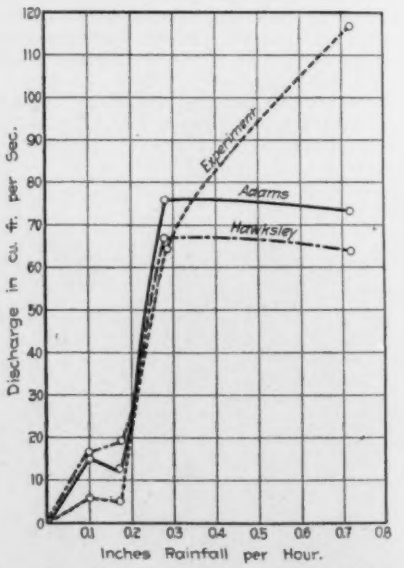


Fig. 5. Observed Storm Water Sewage Discharges at Milwaukee, Wis., Compared with Calculated Results from Adams and Hawksley Run-Off Formulas.

them is beyond the scope of this thesis. Suffice it to say, that the main point brought out by these engineers, after a careful investigation of their work, is the necessity and importance of further data on this subject.

In conclusion, we wish to thank both Mr. Geo. H. Benzenberg, M. Am. Soc. C. E., City Engineer of Milwaukee, and Mr. Boley, City Engineer of Sheboygan, for their kindness and for assistance extended us in carrying out our experiments.